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An Evaluation in China and the UK of a Virtual Laboratory in Materials Science

Thesis for MPhil degree

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April, 2009

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Abstract

This thesis describes the design, development and evaluation of virtual technology-based courseware—Virtual Laboratory in Materials Science used in a tension test that forms part of the course of “Properties of Materials” taught to most first year engineering undergraduates. The effectiveness of this specially developed courseware for virtual laboratory work was evaluated in a pretest—posttest comparative study of the performance of designated subjects between two treatment groups that worked with the courseware and two control groups that worked with a real testing machine. All participants were engineering students studying either with the United Kingdom Open University (UKOU) or with the China Radio & TV University system (CRTVUs).

The findings showed that most students enjoyed using the courseware because the simulated real experiment environment can make them feel personally on the scene. Among all the media used in the courseware, 3D and images were more favoured and more helpful to the students in terms of the usability of the courseware. Sounds were not seen as particularly helpful although some participants agreed sounds made the courseware more interesting.

The result of the research indicated that using the Virtual Laboratory in Materials Science could make a contribution to students’ understanding of the

tensile testing. This evaluation clearly revealed that virtual reality (VR) and virtual environments (VE) technology can facilitate and support engineering course learning or even make learning fun. But when used at times when there were steps that need lots of manipulation, the virtual experiment still had some difficulties that need to be resolved. The research showed that the potential of the virtual testing courseware in promoting concept teaching needs to be tapped further.

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As distance learning my research has been based on online learning and communication so that I could get reference materials from e-library and carry on discussion with my supervisors in the OU and I am most grateful to

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Chapter 1 Introduction

The research in this thesis concerned the development and evaluation of courseware, called Virtual Laboratory in Materials Science for tension testing, which is targeted at students taking undergraduate degree programs in materials science.

The criteria used by professional bodies to accredit engineering programs generally involve items that focus on the ability to design and conduct experiments, as well as to analyze and interpret data that are distinguishing features of the engineering area. Some engineering concepts and phenomena of materials science are especially difficult to understand but can be learned more easily benefitting from practice in a laboratory. Therefore there are some sorts of laboratory work involved in most materials engineering curricula at universities, such as tensile testing, torsion testing and flexural testing. All conventional universities that offer engineering programs have engineering laboratories. Even for distance educational institutes there are various solutions to address this issue, e.g. United Kingdom Open University (UKOU) has a summer school program and China Radio & TV Universities (CRTVUs) hire a laboratory of local universities for the students to engage in laboratory work. But in distance engineering education some students do not have the opportunity to carry out the tests because the working-studying time clashes or a local laboratory is lacking. Therefore experiment kits and software

packages are used as supplementary materials for engineering courses that need to take laboratory work. Further a virtual laboratory that is based upon virtual technology can offer an opportunity to make up for the lack of laboratory work in distance engineering learning programmes.

The Virtual Laboratory in Materials Science was developed in 1999 and was used by nearly 30,000 distance learning engineering students in CRTVUs by the end of 2003. Both pedagogy and technology design are involved in designing the Virtual Laboratory in Materials Science. The courseware is designed to construct a virtual experiment environment to carry out tensile and torsion experiments whilst teaching the basic properties of some typical materials. Considering that a non-immersive VR (virtual reality) or VEs (virtual environments) system is feasible for wide use in educational applications as the cost of this system is far lower than that of an immersive system, non-immersive VR technology was chosen for the courseware. By using 3D, image, sound, and video, the courseware creates a simulation of a real experimental environment to make a user feel personally on the scene.

However:

- Is the courseware useful?
- Do the students learn from using the courseware?
- Do they enjoy using the courseware?
- What aspects of the design of the courseware are successful, and what are not?

These questions could be answered by a carefully designed evaluation. An integrated framework for evaluation including pretest—posttest comparison was used to evaluate the Virtual Laboratory in Materials Science that focuses on comparisons of student performance before and after the tensile experiment has been undertaken.

The study used two treatment groups that worked with the Virtual Laboratory in Materials Science and two control groups that worked with a real testing machine. Engineering students at the UKOU and CRTVUs were involved in two groups in which students were randomly assigned to groups, in the hope of making some cross-cultural comparisons between learners. Triandis pointed out “Cross-cultural research is concerned with the systematic study of behaviour and experiences as it occurs in different cultures, is influenced by culture, or results in changes in existing culture.” (From Li, 2002) But this research focused on special participants who were engineering students in distance learning with assigning learning performances before and after the tensile experiment. Therefore a meaningful cross-cultural comparison could not be made. Nevertheless the results from the groups provided sufficient information to be of interest in itself, without needing to make comparisons between them.

The research is started from literature reviews in Chapter 2. “The technology revolution continues to change the way people live. This is particularly true in

the field of education.” (Birnbaum, 2001) Chapter 2 traces the development of distance education to the fifth generation focused on the impact of technologies. The criteria used by professional bodies to accredit engineering programs that focus on the ability to design and conduct experiments are described in Chapter 2. A key objective in science and engineering education at tertiary level is not only to increase the students’ understanding and knowledge but also to help them to develop the skills necessary to apply them. Furthermore, “it is to give the students an introduction to a community of practice” (Lave et al, 1991), and this means that science learners need to be involved in some types of activity that real scientists perform. Thus, the experience of practical laboratory work is vital but this presents a particular challenge in the distance-learning context.

There is some laboratory work in materials science that is essential and important for engineering teaching programs and this is described in Chapter 3. However, the access to and sometimes the finance of the real laboratory work has been a big problem, especially for the distance learner. Therefore discussion on the situations concerning basic experiments in the UKOU and CRTVUs respectively are referred to in order to reveal the necessity of development of the Virtual Laboratory in Materials Science.

Since computers are becoming more widely accessible and virtual technology is being more and more applied in teaching and learning, development and

application of some kinds of courseware for virtual laboratory work may open one way of addressing such a problem. Several such developments are outlined in Chapter 2 then, in Chapter 4 the researcher describes some details of instructional and technological design for the Virtual Laboratory in Materials Science that is the subject of this research. However, it cannot be assumed that there is a direct relationship between design and the results that the student achieved. There are four current research questions mentioned above. Chapter 2 outlines the essential methodologies of evaluation for learning and further discussion of evaluation for CAL (Computer Assisted Learning). A pretest-posttest approach that “focuses on comparisons of student performance before and after the learning has been undertaken” (Calder, 2001) is also described in Chapter 2.

Chapter 5 describes the methodology used in the conduct of this study. An integrated framework for evaluation including pretest—posttest comparison is used to evaluate the Virtual Laboratory in Materials Science that focuses on comparisons of student performance before and after the tensile experiment has been undertaken. This is applied to groups of students, some of whom used a real tensile testing machine and some just the courseware. The researcher explains the design and procedure of evaluation for the Virtual Laboratory in Materials Science. The Appendix gives full texts of the Evaluation Questionnaires.

In Chapter 6, some statistical analysis of the results is presented with quantitative data obtained from pretest and posttest. The diagrams shown in Chapter 6 indicate some interesting and different results from pretest and posttest between the UKOU participants and CRTVUs participants. Some commentary on the comparative outcomes of evaluating the different groups is provided.

In Chapter 7, the quantitative data and qualitative data are combined together and discussed to explore students' understanding of tensile testing and experimental skills through using the courseware. The SPSS software is used to analyse the data in order to gain some statistical implications. The Paired-samples T-test is used to compare the means of the whole questions scores and test report score of pretest and posttest between the control group that used the real machine and the treatment group that used the courseware.

Chapter 8 presents some conclusions from the findings shown in Chapter 6 and related data analysis in Chapter 7. It is obvious that the use of the Virtual Laboratory in Materials Science can make a contribution to students' understanding of the tensile test. Some recommendations for development of virtual experiments are introduced. At the end of Chapter 8, further improvements for the evaluation are discussed and a summary of this research given.

Chapter 2 Literature review

In recent years, distance education has gained broad attention with greater use of technology. Technology has made dramatic changes in distance education. As a result, some shortcomings inherent to distance learning such as interacting with tutors and other learners, synchronizing learning and laboratory experience are overcome by the Internet, Web and virtual technology. Particular in engineering education a lot of benefits are gained from applications of virtual technology such as virtual reality (VR) simulations and virtual environments (VEs) etc. to improve learning quality not only in distance education but also in conventional education. More and more researchers and developers have drawn attention to the need to evaluate the efficacy of technology in learning due to the trend of educational technology moving from being technology-centred to learner-centred. Although numerous methods exist to evaluate computer software and teaching-learning, it seems that evaluation research coupling virtual technologies with teaching-learning is more important and called-for.

2.1 Development of Distance Education

2.1.1 Definition of distance education

Ding pointed out that “Distance education is a generic term that includes the range of teaching-learning strategies. A kind of formal recognition occurred in 1982, when the UNESCO-affiliated International Council for Correspondence Education (ICCE) changed its name to the International Council for Distance

Education (ICDE). It indicates well the basic characteristic of this form of education: the separation of teacher and learner which distinguishes it from conventional, oral, group-based education” (Ding, 1999). Coincident with this definition of distance education, Keegan described the characteristics of distance education in his book entitled *The Foundation of Distance Education* as follows (Keegan, 1990):

“(1) The quasi-permanent separation of teacher and learner throughout the length of the learning process (this distinguishes it from conventional face-to face education);

(2) The influence of an educational organization both in the planning and preparation of learning materials and in the provision of student support service (this distinguishes it from private study and teach yourself programs);

(3) The use of technical media- print, audio, video or computer-to unite teacher and learner and carry the content of the course;

(4) The provision of two-way communication so that the student may benefit from or even initiate dialogue (this distinguishes it from other use of technology in education); and

(5) The quasi-permanent absence of the learning group throughout the length of learning process so that people are usually taught as individuals and not in groups, with the possibility of occasional meetings for both didactic and socialization purposes.”

2.1.2 Distance education and technologies: five generations

It is helpful “to trace the evolution of distance education in terms of the technologies on which it has drawn” (Daniel, 1999). Taylor introduced five generations of distance education in the CRIDALA Conference 2002 (the second conference on research in distance education and adult learning in Asia):

“The first generation of distance education is the Correspondence Model based on print materials; the second is the Multi-media Model which entails the use of highly-developed and refined teaching-learning resources, including printed study guides, selected readings, videotapes, audiotapes, and computer-based courseware, including computer managed learning (CML), computer assisted learning (CAL), and interactive video; the third is the Tele-learning Model which is based on the use of information technologies, including audio-teleconferencing, audio-graphic communication systems, video conferencing and broadcast television/radio with attendant audio-teleconferencing; the fourth is the Flexible Learning Model that promises to combine the benefits of high quality interactive multimedia (IMM), with access to an increasingly extensive range of teaching-learning resources and enhanced interactivity through computer mediated communication (CMC) offered by connection to the Internet; the fifth is the Intelligent Flexible Learning Model incorporating interactive multimedia (IMM), Internet-based access to WWW resources, computer mediated communication, using automated

response systems” (Taylor, 2002).

2.1.3 Knowledge media and the potential to education

Taylor’s description of generations of distance education demonstrates that technologies play a very important role in the course of the history of distance education. Daniel quotes Laurillard’s analysis for the main types of educational media by dividing them into their canonical forms, the orthodox, unadulterated way of using each one, in his book entitled “Mega-Universities and Knowledge Media: Technology Strategies for Higher Education” (Daniel, 1999). He points out that “Laurillard made this analysis of the teaching and learning qualities of this particular set of media before the expressions ‘knowledge media’ was coined. Indeed, it was only after 1993 that expressions such as the information superhighway, the Internet, the WWW, Java and CD-ROM came into common parlance” (Daniel, 1999). After a series of arguments, Daniel comes to his practical conclusion: “certain media, particularly those which combine a screen and telecommunications, have the potential to mediate more of the teaching and learning activities ... than Laurillard indicated when she examined the ‘orthodox, unadulterated’ way of using them. Putting it another way, increases in telecommunication bandwidth and computing power ‘adulterate’ some media in ways that are potentially helpful to education” (Daniel, 1999).

2.1.4 Mega-Universities: UKOU and CRTVUs

It is clear that distance education is becoming more popular all over the world

along with the development of ICTs (Information and Communications Technologies) taking computers and the Internet as the core technologies. Distance education takes place when a teacher and student(s) are separated by physical distance, and technology, often in concert with face-to-face communication, is used to bridge the instructional gap. These types of programs can provide adults with a second chance at a college education, reach those disadvantaged by limited time, distance or physical disability, and update the knowledge base of workers at their places of employment. So distance education can offer more opportunities for people who want to get higher education. Daniel defined “a mega-university as a distance-teaching institution with over 100,000 active students in degree-level courses. The definition of a mega-university combines three criteria: distance teaching, higher education, and size” (Daniel, 1999). He put The UK Open University (UKOU) and China Radio & TV Universities (CRTVUs) and another nine institutions in the list of the mega-universities. “The UK Open University shows considerable success in achieving the objectives set by its founders. Openness to people led to a 1995 student body numbering over 150,000 in degree credit courses and a further 60,000 working on non-assessed packs” (Daniel, 1999). CRTVUs are a national system including CCRTVU (China Central Radio & TV University) and 44 PRTVUs (Provincial Radio & TV Universities) under which there are 930 branch schools and 2,021 work stations and 22,237 learning centers and there were 1.76 million enrolled students in 2003.

2.1.5 Illustration of digital learning platform system in CRTVUs

Since 1999 CRTVUs have offered a new distance-learning pattern mainly based on the Internet and World Wide Web for Chinese students. Due to the large number of students and wide territory, the teaching network system consists of a digital delivery channel via national satellite net and three-level learning platforms linked by the Internet (Figure 2-1). Learning resources are delivered both through a satellite delivery channel and the Internet. The former has high transmission speed suitable for delivering multimedia messages like video streaming and animation etc. The resources delivered via the satellite net are received by receiver stations with an IP card, but the infrastructure of the station is costly to the individual. The latter is popular and cheaper for individual users but has limitation of broadband especially for video streaming delivery. Given the factors outlined above in Figure 2-1, multimedia learning resources are mainly delivered from the CCRTVU platform to CRTVUs and branch schools platforms by satellite channel so that students can get learning resources by going to the local learning centers to visit local intranet learning platforms or download from the CCRTVU platform directly at home. They can interact with tutors, students and learning materials synchronously or asynchronously through any website from three learning platforms (Fang, 2003).

A variety of online learning resource has been used on the CCRTVU teaching

platform of which the main types include streaming media resources, web courseware and web courses. Streaming media is developed based on the streaming technologies combined with web-page development. It presents teaching content mainly by audio and video streaming with supplementary text and animation etc. Web courseware is a course tutorial package based on multimedia, web-page, streaming media and even simulation. The web-based course is entirely online with learning content, teaching activities and interaction, taking assignments and even examinations and so on.

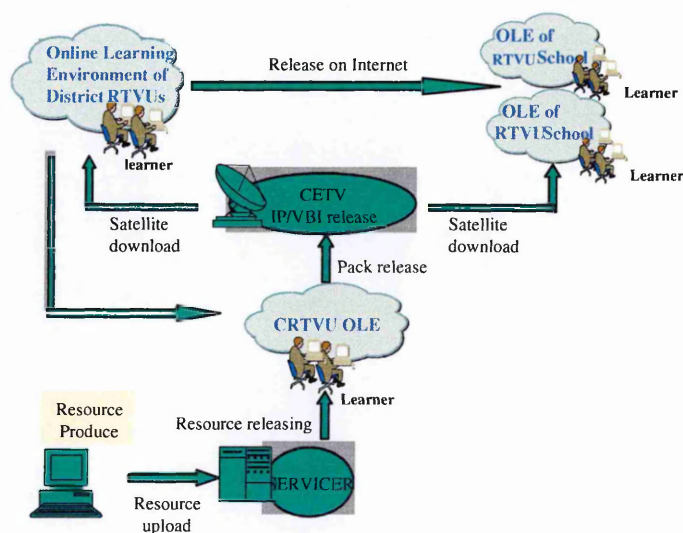


Figure 2-1 Structure of learning platforms of RTVU system in China

2.2 Engineering education and Virtual technology

In the wake of developments in economies and society, there are a lot of changes emerging in application areas of science and technology that are leading transformations in engineering education. On the one hand higher

qualities and comprehensive abilities are demanded of engineers, but on the other hand the number of engineering students has been gradually cut down especially in CRTVUs in recent years. One of the reasons is probably that engineering courses are seen as difficult to learn. Hopefully VR and VEs technology should facilitate and support engineering course learning or even bring some fun to learning.

2.2.1 Characteristics of engineering education

Engineering programs in universities are very important parts of higher education as well as of distance education.

The UK Engineering Council, in Part 2 of SARTOR 3rd Edition, sets out its definition of Engineering:

"Engineering is a profession directed towards the skilled application of a distinctive body of knowledge based on mathematics, science and technology, integrated with business and management, which is acquired through education and professional formation in a particular engineering discipline. Engineering is directed to developing, providing and maintaining infrastructure, goods and services for industry and the community."(The UK Engineering Council, 1998)

The total number of engineering students studying with the Open University in UK since the Open University was founded in 1969 exceeds 10000.

(Endean, 2005) The amount of about 100,000 engineering students studying with the CRTVU system in China between 1979 and 2005 is an even more significant figure.

As well as the development of economies and technologies the demand on engineers keeps growing and the fostering of attainment of capacities has somewhat changed. The United States Accreditation Board for Engineers and Technologists (ABET) addresses the output of graduates by specifying eleven output measures with eight of these containing an 'Ability to...' statement. This list is quoted in full as follows: (ABET, 2004)

"Engineering programs must demonstrate that their students attain:

- a) an ability to apply knowledge of mathematics, science, and engineering*
- b) an ability to design and conduct experiments, as well as to analyze and interpret data*
- c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability*
- d) an ability to function on multi-disciplinary teams*
- e) an ability to identify, formulate, and solve engineering problems*
- f) an understanding of professional and ethical responsibility*
- g) an ability to communicate effectively*
- h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context*

- i) a recognition of the need for, and an ability to engage in life-long learning*
- j) a knowledge of contemporary issues*
- k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.”*

It could be believed that these eleven criteria for accrediting engineering programs are qualities and capacities which all engineers should be provided with nowadays. The second item focuses on the ability to design and conduct experiments, as well as to analyze and interpret data that are distinguishing features of the engineering area. Similarly the UK Quality Assurance Agency for Higher Education (QAA, 2004) sets out practical skills of an engineer in *Academic Standards—Engineering as*

“Graduating engineers will have demonstrated discipline-specific practical skills, particularly concerning laboratory work, project work and use of discipline-specific software. They should be able to:

- *use a wide range of tools, techniques and equipment, including pertinent software;*
- *use laboratory and workshop equipment to generate valuable data;*
- *develop, promote and apply safe systems of work.”*

For this purpose all conventional universities that offer engineering programs have engineering laboratories. Even for distance educational institutes there

are various solutions to address this issue, e.g. the OU have a summer school program for the students to engage in laboratory work. In the technology faculty of the Open University there are three courses holding one-week summer schools for course experiments and practices. (Endean, 2005) However, it is impossible for all students to have this opportunity because they cannot arrange time away from their employment or families or some cannot afford the fee for the summer school, etc. Therefore experiment kits and software packages are used as supplementary materials for engineering courses that require laboratory work. Likewise most CRTVUs hire laboratories in local conventional universities for their students to carry out engineering experiments but computer-based experiments or even on-line experiments are becoming popular recently.

2.2.2 Applications of virtual technologies in engineering

Virtual technologies are new computer technologies that offer VR simulations and VEs through which to learn. Applications of virtual technologies for educational purposes are such as virtual laboratories, virtual tutorials, virtual classrooms, and virtual learning environments and so on. With the development of VR and VEs, it is now possible to simulate engineering and science laboratory projects on a computer. With Internet access, it is now possible to offer students "virtual laboratories" via the WWW. "Experiment-oriented problems can be offered without the overhead incurred when maintaining a full laboratory." (Karweit, 2000) Therefore virtual

laboratories which are based on VR or VEs are a rapidly emerging computer interface that offers potential to increase the impact and effectiveness of these educational simulators. “The main goal of VR and VEs is to completely immerse the user within the simulation, and to make him or her believe that they are physically inside the computer generated environment.” (Bell et al, 1996).

After a thorough review of the literature regarding virtual laboratory and experiments, two distinct categories of VR and VEs applications can be identified. The first category is known as “immersive VR or VEs, is based on HMD (helmet-mounted display), CAVE, or immersive display technologies.” (Obeysekare et al, 1996, Chen et al, 2005) The second category, “non-immersive VR or VEs, or, sometimes, desktop VR or VEs, presents images on a normal monitor and allows the user to interact with the computer-generated images. Although the user is not technically immersed, it is considered as a VR system because it is comparable to viewing a real world through a window.” (Chen et al, 2005, Obeysekare et al, 1996)

With regard to immersive VR or VE applications, learners using some devices can acquire and apply knowledge in a much more realistic way including seeing, hearing, touching and feeling. For example, Studierstube (Fuhrmann et al, 2001, Schmalstieg et al, 2001) is a virtual environment that enables computer generated images to be overlaid over reality using semi-transparent

head-mounted displays (HMDs). Users use PIP (the Personal Interaction Panel) /Pen to control the simulation. They can see each other through the HMDs and additionally perceive the virtual imagery stereoscopically displayed between them. Another sample is Virtual Haptic Back. VHB is “a series of computer-based, haptic simulations of the human body to assist students in the learning of palpatory techniques that consists of highfidelity graphical model of the human back coupled with dual PHANTOM 3.0 haptic interfaces to allow user interaction.” (Williams et al, 2004)

Both examples show such systems enable computer generated images to be overlaid over reality by using immersive technology in order to enhance the effectiveness of visual sense, interactive performance and even tactile feelings. Therefore immersive VR or VE applications could be applied as an educational tool to support leaning processes by enhancing the students’ understanding of contents to be visualized three-dimensionally and to be palpable. It seems that immersive VR or VE applications are appropriate to meet the need of engineering education on “practical skills, particularly concerning laboratory work, project work and use of discipline-specific software” (QAA, 2004). Thus immersive VR or VEs can be used in development of experiment kits and software packages for engineering courses that need to include laboratory work in the OU and CRTVUs. However they may be of limited feasibility for wide use in educational areas as they depend on complex and expensive peripherals besides normal

computer display and conventional input devices, such as mouse or keyboard. Despite intense research in immersive VR or VE applications, until recently there are very few examples of summative evaluation coupling VR/VE technology with students' learning outcomes.

Non-immersive VR or VE have found an increasingly wide utilization in the educational field. There are two main technical types of the applications. One sort is the simulation software package, such as ViBE (Subramanian et al, 2001), the CAEME center (Oriol et al, 1996), and Virtual Testing of Laminates (NPL, 1999). For example, Subramanian et al (2001) introduced ViBE: "Spectrophotometry Laboratory offers a virtual machine to measure the concentration of a substance in a solution by passing light of a specified wavelength through it to familiarize students with the spectrophotometer and its use." Another sort is the Web-based virtual laboratory such as Virtual laboratory (Karweit, 2000), IrYdium and VTLS. For instance, the IrYdium project "provides an environment in which students can select from hundreds of standard chemical reagents and combine them in any way they see fit" (Yaron et al, 2001). VTLS "allows test operators and observers to control and monitor tests at remote locations via the Internet." (VTLS, 2002) Basically simulation software packages use 3D and 2D images, and video and audio multimedia to simulate reality in the local computer. Moreover Web-based virtual laboratories use lower capacity graphics and audio in order to transfer at high speed via the Internet.

The non-immersive VR or VE application does not depend on complex and expensive peripherals. The use of a normal computer display and conventional input devices in a non-immersive system means that the cost of this system is far lower than that of an immersive system, which makes such systems feasible for widespread use in educational applications. That is the main reason to choose Non-immersive VR or VEs as a technical model of 'a Virtual Laboratory in Materials Science' which was one object of this research.

Basically a virtual laboratory that is based on a VR or VE consists of a real-time 3D or 2D image display to simulate real experiments, a graphical user interface using a mouse or keyboard as input devices, and mathematics modeling or general algorithms to calculate the data for the experiment.

“Compared to real experiments, virtual laboratory in a VR or VEs can offer advantages in terms of accessibility, convenience, cost, safety, and versatility” (Witmer et al., 1996). It is obvious that virtual laboratory can play an important role in engineering education especially in distance education. Students can carry out experiments repeatedly in a virtual laboratory based on VR or VEs. It can thereby help learners to master laboratory skills. “Efficacious VE-based training results when knowledge learned through experience in a virtual world improves the performance of the activity in the

real world.” (Derek et al, 2003)

2.3 Evaluation of learning

2.3.1 Definition of Evaluation

Schuemmer (1991) collected a number of statements about what evaluation is:

- *"Evaluation is an observed value compared to some standard. "* (Stake, 1983)
- *"Evaluation is marshalling of information for the purpose of improving decisions" (Thompson, 1975)*
- *"Evaluation is the process of delineating, collecting and providing information useful for judging decision alternatives. ...Evaluation is the determination of the worth of a thing. It includes information for use in judging the worth of a program, product, procedure or objective or the potential utility of alternative approaches to attain specific objectives" (Wentling & Lawson 1975, from Wittman, 1985)*
- *"...program evaluation refers to the use of research methods to measure the effectiveness of operating programs." (Ruthman, 1980)*
- *"The purpose of evaluation research is to measure the effects of a program against the goals it set out to accomplish as a means of contributing to subsequent decision making about the program and improving future programming." (Weiss, 1972).*
- *"Evaluation research is the systematic application of social research procedures for assessing the conceptualization, design, implementation,*

and utility of social intervention programs." (Rossi & Freeman, 1989)

- *"By the term evaluation, we mean systematic examination of events occurring in and consequent on a contemporary – an examination conducted to assist in improving this program and other programs having the same general purpose." (Cronbach et al., 1980)*
- *"...we may define evaluation broadly as the collection and use of information to make decisions about an educational program. The program may be a set of instructional materials distributed nationally, the instructional activities of a single school, or the educational experiences of a single pupil. Many types of decisions are to be made, and many varieties of information are useful. It becomes immediately apparent that evaluation is a diversified activity and that no one set of principles will suffice for all situations." (Cronbach, 1983)*
- *"Evaluation is the process of delineating, collecting and providing information useful for judging decision alternatives." (Stufflebeam et al. 1971, from McCormick & James 1989, p. 172)*
- *"Evaluation is the process of conceiving, obtaining and communicating information for the guidance of educational decision-making with regard to a specified programme." (MacDonald, 1973, from McCormick & James 1989, p. 172)*
- *"Curriculum evaluation is the process of delineating, obtaining and providing information useful for making decisions and judgments about curricula." (Davis, 1981, from McCormick & James 1989, p. 172).*

Therefore conducting evaluation has different purposes. The aim of evaluation in the case of any organization must be to support that organization in achieving its goals. “Evaluation is used, or should be used, to enable institutions to operate as learning organizations” (Calder, 2001). Evaluation is a scientific and useful means not only for judging the worth of a program but also for measuring the effectiveness of a program against its design and goal.

2.3.2 Evaluation of Distance Learning

Isaac talks of “assessment for learning as frequently the preoccupation of university teacher, but assessment presents many opportunities to enhance students’ learning” (Isaac, 2001). “For distance education, the purpose of assessment is to measure progress made by the learner so that efficacy of instruction can be analyzed” (Birnbaum, 2001). Many of the fundamental concepts and goals of educational evaluation are similar to assessment, but there are some issues that differentiate evaluation particularly of distance learning due to the characteristics of distance education above-mentioned. For example, more emphasis is usually placed upon “evaluation of multimedia learning technologies” (Whitelock, 2000) and “evaluation of programmes of study” (Calder, 2001).

To summarize, evaluation for learning could be used to evaluate all components of education including how the teacher is teaching, the student

learns, the quality of the learning materials and how useful are multimedia products and so on.

The two main types of educational evaluation that can be found in the literature on evaluation are usually described as formative and summative evaluation. (Scriven, 1976, Calder, 2001, Whitelock, 2000, Bowman, 2002) Other types of evaluation, such as mixed assessment (Isaac, 2001), illuminative evaluation (Calder, 2001), descriptive or judgmental evaluation, pre-ordinate or responsive evaluation (Rekkedal, 2000) are also discussed by some authors.

2.3.3 Formative and Summative Evaluation

Formative evaluation is that evaluation which is used with the intention of developing or improving the functioning of an activity or the effectiveness of components. (Calder, 2001; Birnbaum, 2001) Whitelock suggests “formative evaluation investigates the software/courseware design as it is being developed” to obtain the invaluable feedback from the very intensive observation of a small number of students working in pairs. “The sorts of data produced from formative evaluation are not open to statistical analysis, therefore not usually generalizable.” (Whitelock, 2000) For the usability evaluation of VEs, Bowman et al propose formative evaluation as “an observational, empirical evaluation method that assesses user interaction by iteratively placing representative users in task-based scenarios in order to

identify usability problems, as well as to assess the design's ability to support user exploration, learning, and task performance.” (Bowman et al, 2002)

“Summative evaluation is that evaluation where the intention is to form a judgment or conclusion about either the absolute or the relative merits of whatever is the focus of evaluation.” (Calder, 2001; Birnbaum, 2001)

“A summative evaluation is usually undertaken at the end of the project to investigate how the material is embedded into a variety of learning contexts”. (Whitelock, 2000) In the context of the usability evaluation of VEs, Bowman et al describe summative evaluation “as a statistical comparison of two or more configurations of user interface designs, user interface components, and/or user ITs. As with formative evaluation, representative users perform task scenarios as evaluators collect both qualitative and quantitative data.” (Bowman et al, 2002)

But Calder pointed out that “it would be a mistake, however, to think of the distinction between the two forms of evaluation as formative if carried out during the development phase and summative if carried out during the presentation phase. Both formative and summative approaches can be used during materials development and materials presentation stages” (Calder, 2001).

2.3.4 Models and Approaches for Educational Evaluation

For methods and techniques of enquiry that can be used in carrying out evaluation, Calder (2001) introduced a pretest-posttest approach that

“focuses on comparisons of student performance before and after the learning has been undertaken. When used in a true experimental design, this allows relatively straightforward assessment of a pedagogical or technological intervention by detecting differences in behaviour between two points in time – before and after. This assessment strategy is very common in educational research since its implementation is relatively non-intrusive and its analysis does not normally require more advanced statistical procedures. A wide variety of pretest-posttest comparison designs are available.” (Calder, 2001)

There are more details of the pretest-posttest approach described in web-based literature entitled “Assessment Tutorial: Pre-Post Comparison” presented by the New Jersey Institute of Technology (NJIT, 2005). They described

“all true experimental designs in which students are randomly assigned to groups and identical measures are used to assess the learning outcomes of each group. For this method random assignment gives an assurance that the groups are comparable and that the observed differences in learning are the result of the intervention. True experimental designs, then, provide the most reliable information on the effectiveness of a given intervention.”(NJIT, 2005)

But Calder agreed with Flagg's (1990) opinion about the methodological drawbacks of pretest-posttest comparison approach "such as the drop-out from the test group, possible effects of external events, such as TV maths programmes at home, or extra help from parents, and the effect on the group of constant testing." So suggestions for improving the NJIT 'Assessment Tutorial' approach above include the following:

"It's extremely important that the observations are independent; therefore, the researcher must make sure that the control or comparison groups are not inadvertently exposed to the intervention used in the experimental condition and that participants in the study do not communicate with one another about their experiences. It's also very important that the groups do not differ in ways that are not controlled." (NJIT, 2005)

2.4 Evaluation of CAL

As mentioned above, numerous methods exist to evaluate learning. However, "when technology is involved too, the evaluating process becomes more complex" (Whitelock, 2000) because not only pedagogies including learning content, teaching methods and instruction are to be evaluated but also the effects of technologies such as multimedia, interaction, delivery mechanism etc. on learning.

Computer-assisted learning programs (CAL) are being used increasingly in

higher education. They have been applied widely for supporting different learning needs including interactive tutorials which provide patient tutoring with instant feedback on learning difficulties, simulation of physical phenomena which enrich practical sessions, and data manipulation which check students' calculations. As described in section 2.2, VR or VE have been used increasingly in CAL such as the virtual laboratory for the course 'What is engineering' developed by Johns Hopkins University and the Virtual Microscope developed by the UKOU. So most virtual computer-assisted learning programs focus on imitating the real experiment process and enable operation by students. The emphasis of evaluation of this sort of learning program would be: What are the design features which not only offer an experience similar to using a real testing machine but also enable such virtual instruments to be effective in illuminating the process of tests and in developing students' experimental skills? Does the virtual instrument make for an educative testing environment for the students? What is the value of visualisation and sound as an aid within the virtual testing environment? How can students navigate the virtual testing machine easily without just blindly following instructions?

CAL evaluation is the process of judging the value of a piece of educational software for a particular use, by systematic collection and interpretation of data. Jones et al (1996) and Draper et al (1998) proposed an integrated framework for CAL evaluation whose "concerns are to evaluate the

effectiveness and quality of CAL, whilst at the same time, investigating the educational situation as a whole and focusing on the learners." There are three dimensions to this framework which include the context, interactions and outcomes that transpire throughout the learning process. They stress "the importance of understanding why a particular piece of software was developed in the first place and how elucidating the 'context' of any multimedia learning system should be acknowledged and made explicit." (Whitelock, 2000)

There are numerous traditional approaches such as pretest-posttest, cognitive walkthrough and heuristic approaches (Bowman et al, 2002) used in formative and summative evaluation for CAL. In particular with VR/VEs, a review of literature indicates that usability evaluation (for example, Bowman et al, 2002, Whitworth et al, 2003) has become a major focus. And Bowman et al (2002) present two important evaluation approaches to evaluate the usability of interactive computer applications, especially for evaluating VEs. One is testbed evaluation, which focuses on low-level ITs in a generic context, and another is sequential evaluation, which applies several different evaluation methods within the context of a particular VE application.

2.5 Case studies on evaluation of VR or VEs

A review of literature indicates that systematic evaluation of educational applications of VR or VEs often lags behind development efforts particularly

for evaluating both pedagogies and technologies. Some of them are initial or preliminary evaluation. For example, Bell and Fogler (1996) describe the first student evaluations of an educational module that uses a virtual reality based simulation to aid students in performing a safety and hazard evaluation of a chemical production facility. Shin et al (2002) used a survey questionnaire to evaluate a web-based, interactive virtual laboratory system that is for unit operations and process systems engineering education. The virtual lab received very high praise for the efficient use of the lab time, accessibility of the virtual lab and the possibility of its replacing some real labs. Brooks et al (2002) employed a pretest and posttest method to evaluate the efficacy of using a virtual kitchen for the vocational training of people with learning disabilities. The research found virtual training to be as beneficial as real training and more beneficial than a workbook with no training in the food preparation tasks. However, virtual, real and workbook training were found to be equally beneficial in the hazard identification task. Subramanian et al (2001) presented a summary of preliminary results from the ongoing evaluation of the Virtual Biology Labs (ViBE). "This research involved 18 students surveyed with questionnaire on the usefulness of the simulations in explaining the different stages of mitosis via the dynamic representations and simulations that were embedded in this lab. The results showed that students in general had a positive attitude towards the lab on mitosis and specifically liked the fact that they could replay and watch the process as many times as they needed." Chen and Toh (2005) "carried out on the pilot program of

VR-Based Learning Environments in appropriate educational settings, measuring learner performance on pre-and posttests.”

2.6 Summary

From the literature, we can see the picture of distance education that is developing rapidly with technologies. The important characteristic of distance education is “quasi-permanent separation of teacher and learner throughout the length of the learning process” (Keegan, 1990). For engineering education, practical skills, particularly concerning laboratory work are set in academic standards. This is a challenge to engineering disciplines in distance education as traditional experiments are taken in a real laboratory. Computer-based experiments or even on-line experiments are one of the solutions to overcome the difficulty of providing laboratory work in distance education. Particularly with the development of VR and VEs, it is now possible to simulate engineering and science laboratory projects on a computer as virtual laboratories. Almost simultaneously with the educational application of new technology, researchers have begun to discuss with what kind of effectiveness in experimental knowledge and skills students can learn using VR/VE applications. Therefore, the usefulness of VR/VE application has to be supported by the results of evaluation research. Formative and summative evaluations are the main methods for educational evaluation. The pretest and posttest approach is currently employed during evaluation of CAL. The review of literature indicates that systematic evaluation of educational

applications of VR or VEs often lags behind development efforts particularly for evaluating both pedagogies and technologies. There are very few examples of summative evaluation coupling VR/VE technology with students' learning outcomes. Thus it has a wider significance to study the entire process of VR/VE application evaluation including the context of the application, the technology, the academic design, the evaluation method and the results analysis.

Chapter 3 Basic experiments in Materials Science

As described in Chapter 2, the criteria used by professional bodies to accredit engineering programs generally involve an item that “focuses on the ability to design and conduct experiments, as well as to analyze and interpret data that are distinguishing features of the engineering area.” (Chapter 2, pages 23-25) Therefore there are some sorts of laboratory work involved in most materials engineering curricula at universities, such as tensile testing, torsion testing and flexural testing.

In this chapter, the contents of the tensile testing and the testing machines are introduced in detail. The torsion test is introduced but this test was only applied to the “treatment groups” (see Chapter 5, page 64) to compare some functions with the tensile test in the Virtual Laboratory in Materials Science. Discussion on how basic experiments are conducted in the UKOU and CRTVUs are referred to in order to reveal the necessity of development of the Virtual Laboratory in Materials Science.

3.1 Tensile Test

In order to study materials strength and behaviours, a specimen in the form of a bar or rod is stretched in a testing machine and the load is measured directly. “The extension can be applied by a screw-driven mechanism or by an accurately controlled hydraulic piston. The extension of the specimen is measured either by monitoring the displacement of the piston, or more

accurately by measuring the change in a known length (the gauge length) in the parallel-sided section of the specimen. The output of the machine as a result of performing a tensile test on a specimen is therefore a set of values of loads and matching extensions.” (The Open University, 1997)

There are various types of the testing machines. For example, Figure 3.1 shows a Hounsfield Tensometer, a machine of manual testing type, which was used by the control groups in this research. In the wake of developments in computer and ICT technology, a materials testing machine of the latter type is controlled by a computer with control software whose “programmable functions include running a test to a pre-determined force/torque, displacement, or time to break, as well as graphical interrogation of results.” (Mecmesin’s website, 2008) Figure 3-2 shows a universal testing machine, AG-1 Series that was an archetype for the virtual testing machine.

Figure 3-3 is a graph of load versus extension that is generated by the X-Y recorder attachment of the testing machine. For example, through a tensile test for a low carbon steel specimen, certain characteristics are apparent from force-extension curves and some data on the behaviour of the material under test can be obtained, such as the values of force and extension corresponding to the load at yield point, and the maximum load. Some important phenomena can be viewed such as some permanent (plastic) deformation in the specimen

with “necking” occurring as the extension increases when the force is seen to drop off.

Because force (F) can be converted into stress ($\sigma = \frac{F}{A}$) and extension ($\Delta l = l_1 - l_0$) can be converted into strain ($\epsilon = \frac{\Delta l}{l}$), “force-extension curves can be converted into stress-strain curves” (see Figure 3.4). Stress-strain curves are “geometry-independent, these provide more fundamental data on the behaviour of the material under test than do force-extension curves.” (The Open University, 1997) Further, some materials properties can be calculated by the data from the tensile test or can be read directly from the stress-strain curves. For example, the yield stress can be calculated from the load at the yield point divided by the original cross section area. The tensile strength (UTS) can be calculated from the maximum load divided by the original cross section area. The elongation at failure can be calculated from the difference between the fracture gauge length and the original gauge length divided by the original gauge length then multiplied by 100.

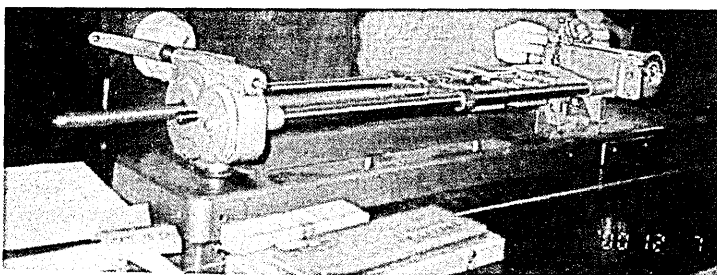


Figure 3-1 A Hounsfield Tensometer



Figure 3-2 A Universal Testing Machine

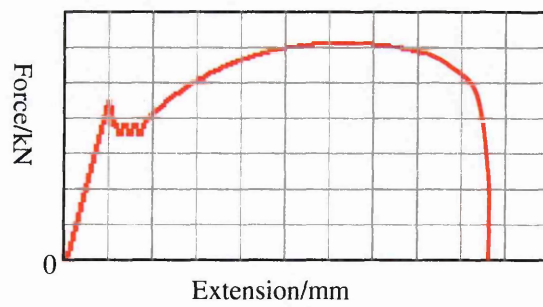


Figure 3-3 Force-Extension graph of steel

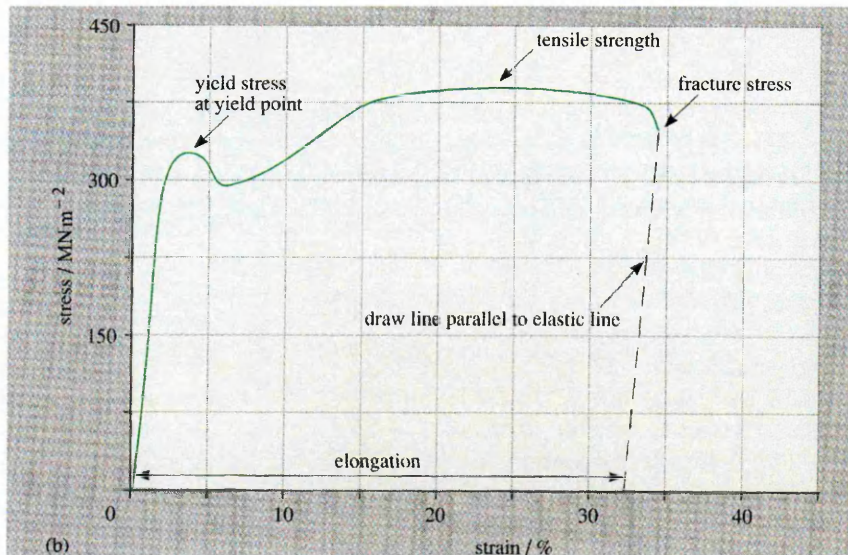


Figure 3-4 Stress-strain curve for steel

3.2 Torsion test

A torsion test is to observe materials' shear failure under torsion. The specimen will be fitted with a measuring device called a troptometer, which gives precise angle of twist measurements.

Torque is gradually applied and readings from the troptometer are taken at set intervals of torque. Torque is increased until rupture occurs. Figure 3-5 shows a torsion testing machine and Figure 3-6 is a graph of angle of Twist versus Torque for mild steel.

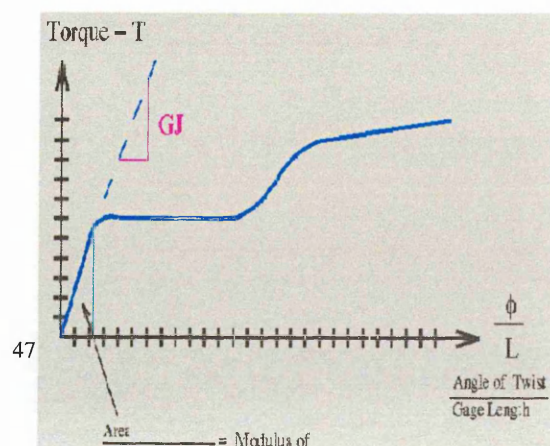
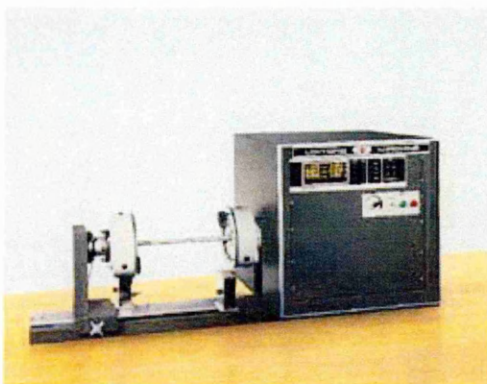


Figure 3-6 Twist-Torque graph of mild steel

3.3 Situations of the basic experiments in the UKOU and CRTVUs

The basic experiments in material science, tension testing, torsion testing and bending testing are important and primary experiments. As a requirement of the syllabus, this means every student in materials science should know about the basic methods of establishing materials properties and preferably they should have conducted a number of tests for themselves. But the cost of the testing instrument is very high and together with the cost of the sample materials, this places a practical limit on the number of students undertaking this kind of practical operation.

The OU students who take the course T203 Materials: Engineering and Science learn the tensile test by watching the Structural Materials video. Endean introduced the video

“as a 'filmed demonstration' of mechanical testing and it covers both tensile testing and impact testing of metals and polymers. A presenter (lecturer) talks directly to the viewer through the camera. The presenter also provides an audio commentary for the sequences where he is not in view. The storyline for tensile testing starts with an account of what tensile testing is for. Then the presenter shows a typical dumbbell sample

and how it is placed in the machine. The tensile test is carried out in real time on camera and the use of an x-y plotter to record load and extension is explained. The phenomenon of necking is shown in close-up. Finally, the presenter explains how the results of the test are calculated and recorded.” (Endean, 2008)

As described in Chapter 2, “CRTVUs is a national system including CCRTVU and 44 PRTVUs (Provincial Radio and TV Universities) under which there are 930 branch schools and 2,021 work stations in 2003.” In terms of teaching operating mechanism, CRTVUs at different levels perform their different roles. “The CCRTVU takes up the responsibility to draw up curriculum and teaching plan; organizing the work of designing and developing teaching materials; making examination papers and stipulating the marking standard. The RTVUs are responsible for implementing the teaching programme.” (Ge, 2007) The local work stations are in charge of organizing face-to-face tutorials.

For the CRTVUs students of materials engineering before 1999, the local RTVU or work station contacted the local university to hire a laboratory, paying them a fee. Then the students needed to go to the laboratory within a fixed time to conduct the tests. But most of them generally could only “watch” the tests conducted by one person due to a large group needing to share a testing machine. More than that, some students often did not have the

opportunity to carry out the tests at all because the working-studying time clashed or a local laboratory was not available.

Since 1999, because a CD-ROM of the Virtual Laboratory in Materials Science had been published in China, students could use the software for the experiments on a computer anywhere they wanted without paying any more as they received the course textbook packaged with a CD-ROM of the software. There were over thirty thousands students of CRTVUs who used the Virtual Laboratory in Materials Science from 1999 to 2003 replacing the real testing or as supplementary material for preparatory lessons before taking the real testing.

Chapter 4 Design and development of the Virtual Laboratory in Materials Science

The basic experiments of materials engineering were introduced and demands for the Virtual Laboratory in Materials Science in distance engineering education discussed in the preceding chapter. Design and development of the Virtual Laboratory in Materials Science will be covered in more detail in this chapter.

4.1 The design of the Virtual Laboratory in Materials Science

With regard to the design of courseware, both pedagogy and technology design are involved. First of all, some technology issues were considered for design of the Virtual Laboratory in Materials Science.

At the start of the design and development of the software in 1997 there were few similar materials found by searching the Internet and library catalogues. Recently the virtual laboratory is more popular because of the increase in computing and virtual technologies, as described in Chapter 2, which include two distinct categories of VR systems, immersive and non-immersive VR or VE. According to discussion in Chapter 2, the non-immersive VR or VE system is feasible for wide spread use in educational applications as the cost of this system is far lower than that of an immersive system due to the use of a normal computer display and conventional input devices in a non-immersive system.

Therefore the non-immersive VR was chosen for the Virtual Laboratory in Materials Science. As discussed in Section 3.3, the main purpose of developing the Virtual Laboratory in Materials Science, referred to as a virtual instrument, was to handle tension and torsion experiments for distance learning. Hence the courseware that was an adaptive tension and torsion machine control system was developed based in a VR consisting of a real-time 3D and 2D image display simulating real experiments, a graphical user interface using a mouse or keyboard to manipulate, and general algorithms to calculate the data for the experiment.

Another important issue relates to pedagogy design. Hill separated certain abilities into knowledge, skills, understanding and know-how. In summary, these are defined as follows:

- *"Knowledge is information that can be recalled;*
- *Skills are things people can do without thinking too much about how to do them;*
- *Understanding is the capacity to use concepts creatively in problem-solving, in design, in explanations, in fault diagnosis and correction, in asking searching questions, etc;*
- *Know-how is also a problem-solving capability, but it is based on experience rather than on conceptual learning. "(Hill et al, 1998)*

Referring to the standards for engineer as ABET and QAA mentioned in Chapter 2 and some teaching abilities described above, the goal of design of the Virtual Laboratory in Materials Science was to enable engineering students in distance learning to:

- have laboratory skills and gain some ICT capacities,
- understand fundamental properties of some materials such as steel, copper etc from the experiments.

As described in Chapter 3, real testing machines for tension and torsion have been developed from the early version operated by hand to the later version controlled by computer. Modern real testing machines just need finger press switches on the operating console. That is possible for imitating the real testing machine and the real testing process by virtual technology. The procedure of conducting tension and torsion tests may be learnt easily as virtual tests can be re-run as often as required. Knowledge of basic properties of some materials can be taught well by hypermedia as was employed in the computer application.

“Understanding is the most difficult of all the abilities to teach as it is very much an iterative process between grasping concepts and learning to apply them in real situations.” (Hill et al, 1998) The computer application can help in this process by imitating the real testing phenomena and focusing on the key points, then giving the relevant concepts to explain what has happened.

“The tensile test is probably the simplest and most widely used test to characterize the mechanical properties of a material.” (Drakos and Moore, 2003) The Virtual Laboratory in Materials Science was designed to construct a virtual experiment environment to carry out tensile and torsion experiments whilst teaching the basic properties of some typical materials. So there are virtual experiment instruments for the tensile, the torsion experiments and another virtual instrument for the bending experiment in the application. And each component of the Virtual Laboratory in Materials Science also has the function of giving instruction like an experiment tutor.

There are two different instruction models in the application. One is individual control instruction that allows students to conduct the experiment on his/her own. If students take wrong steps or have problems, they need to go to the virtual library or the help function to find relevant instructions. Another model is the step-by-step control instruction that offers a clear and direct instruction of the process which the students follow to conduct the experiment. The former was used for the tensile test and the latter was used for the torsion test in this study.

Students needed to read the text book before they went to the application. They learnt what the tensile, torsion and bending experiments were but they had not taken the real tests at that stage. A self-test about how much he/she

knew about the experiments before starting the experiment was designed as a component with instant feedback to the user. The database of the Virtual Laboratory in Materials Science recorded the user's trace and check the data from the tests. Then it gave the score of the experiment after the test was finished and the experimental report was completed. For more knowledge of the experiments there was a library for relevant knowledge such as different types of testing machines, specimen and ruler, electronic strain gauge, etc.

The mind map of design is shown in Figure 4-1.

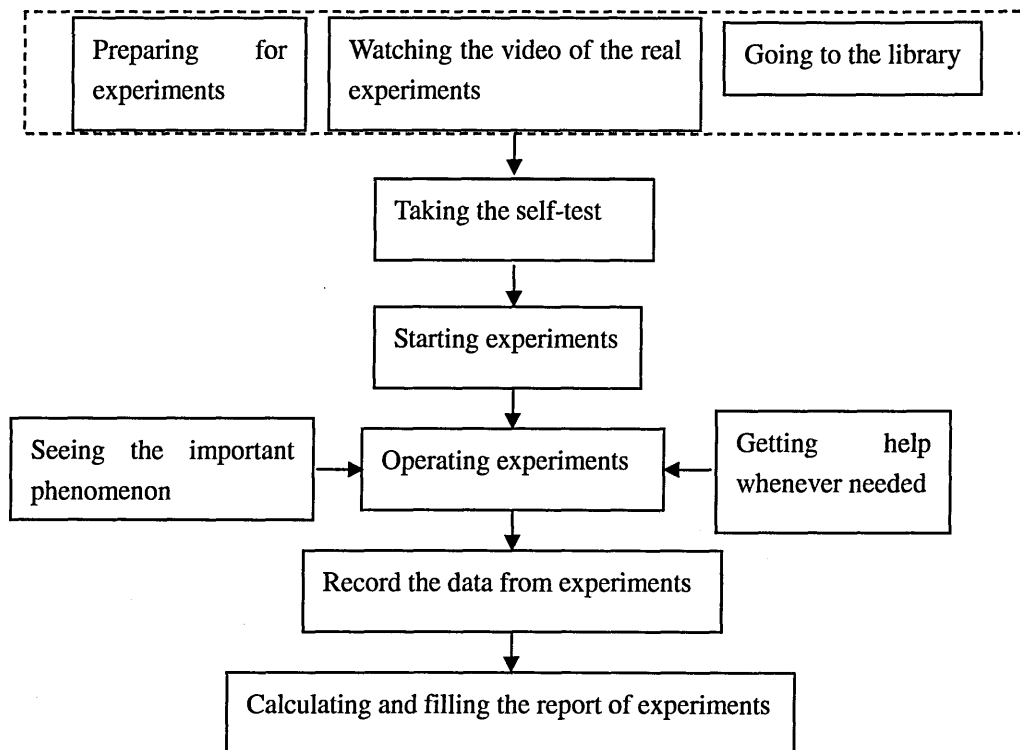


Figure 4-1 Mind map of design

4.2 The development of the Virtual Laboratory in Materials Science

There was a team for the application development that including academics,

technicians, a graphic designer and programmers. The key person, the team manager, was someone who put academics, laboratory and programming together. This role was held by the author.

During the first stage, the team took a real testing machine, an AG-1 Series Precision Universal Tester made by The Shimadzu Corporation as an archetype. The Shimadzu Corporation gave the team considerable support. The team members used the machine The Shimadzu Corporation offered free of charge to take the tests.

The graphic designer imitated front pages for every part of the machine using 3D and Photoshop. The information contained within the application was gleaned from the lecture course and the laboratory session that the application was to replace. Then a draft storyboard of the application was written by the team manager and then was discussed by the team. The storyboard of the application showed the logical relationship of pages and hot words and hot zones. The team member who is a technician of a laboratory of Qinghua University was in charge of the data for the experiments from the results of the real tests and adjusted the data following the principles of materials properties.

The application was developed using Authorware for programming. Although a detailed storyboard was very useful for the programmers they still expected

the team manager to work with them to make sure where the program should go.

The application's format was based mainly on a two level structure, Figure 4-2. There were four Authorware files which were main.a5p, lashen.a5p (tensile), niu.a5p (torsion) and wan.a5p (bending) and some folders including .avi video files and sound files etc. in the same folder. The framework of main.a5p shown as figure 4-3 was to achieve the first level of the programme that offered jumping functions to tensile, torsion and bending testing laboratories.

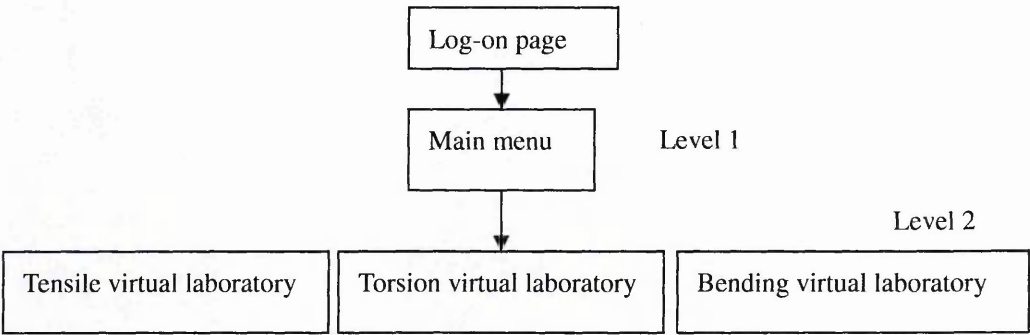


Figure 4-2 Flowchart of two-level structure of the application

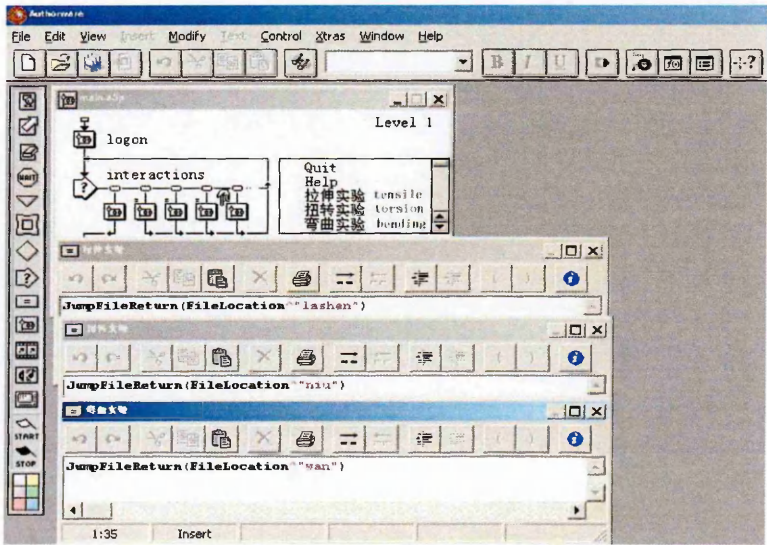


Figure 4-3 Framework of main.a5p

The framework of lashen.a5p shown as figure 4-4 was to achieve all functions

described in the mind map of the design (see Figure 4-1).

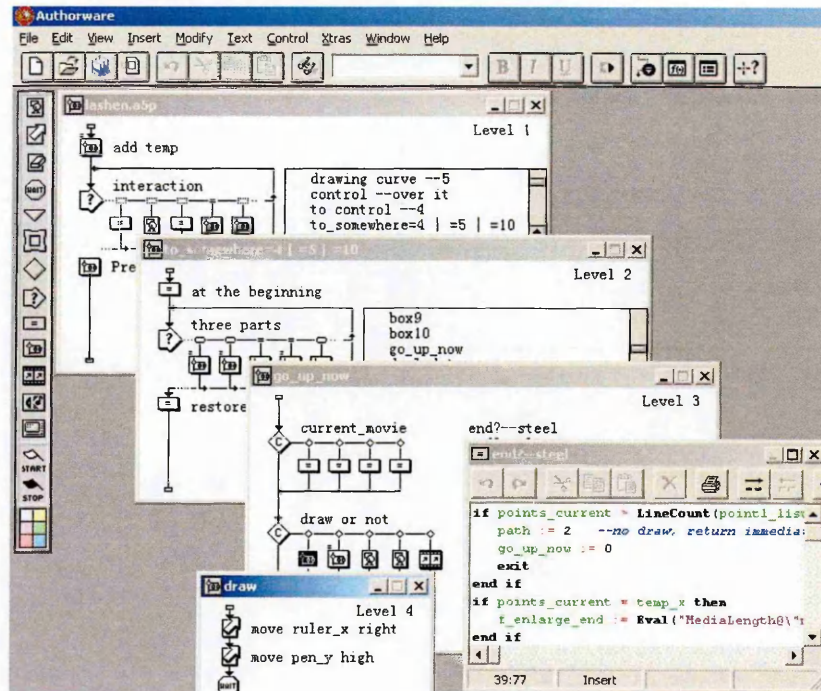


Figure 4-4 Framework of lashen.a5p (tensile)

When the programme of lashen.a5p is run, the interface of Virtual tensile testing laboratory is as shown in Figure 4-5. There is a virtual testing machine whose archetype was a universal testing machine, AG-1 Series (Chapter 3, page 43), the control panel to conduct the test, the X-Y recorder to record force-extension graph, the specimen box, the video of a real tensile test, a library, some multimedia learning materials for preparing for the tensile test and the interactive self-test to check understanding about the test.

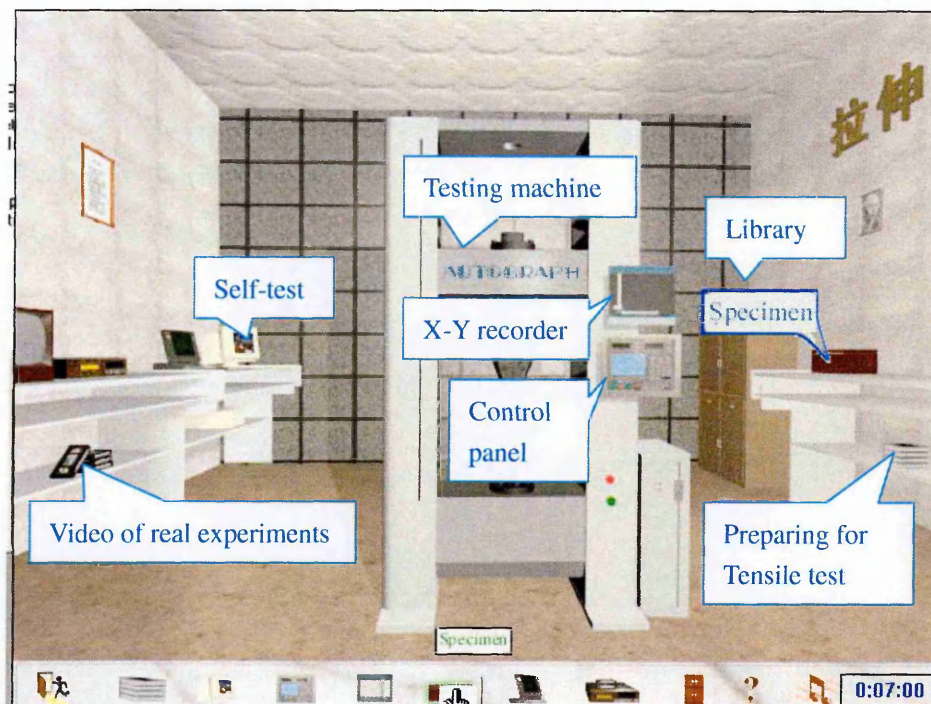


Figure 4-5 Virtual tensile testing laboratory

The sample of the program included as Appendix 5 gives the result shown in Figure 4-6 that is a scene of the specimen fractured during the tensile test. To the left of the screen are grips and a fractured specimen. The right upper part of the screen is the force-extension graph recorded by the X-Y recorder. The right lower part is the control panel.

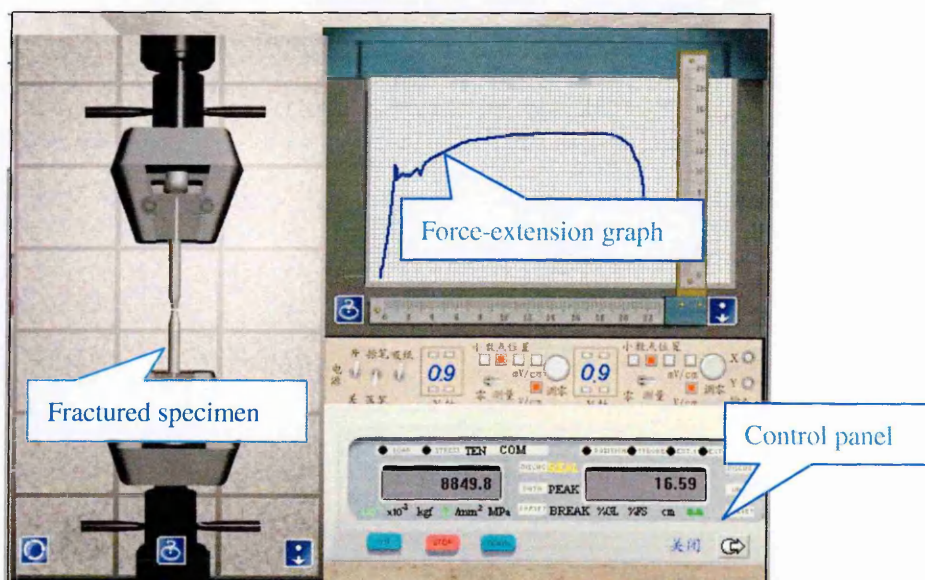


Figure 4-6 Procedure of tensile test

4.3 Using the Virtual Laboratory in Materials Science

When students arrive at the virtual laboratory, there are icons he/she can click on which are Pre-view, Video, Library, Report, Self-test, Specimen, Control panel, X-Y recorder and Help.

When moving the cursor it becomes a turn-left arrow. Then by clicking the mouse and similarly for a turn-right arrow, it seems you are walking around the room. In this way, the student was taken through the standard sequence of events in a tensile test, starting with selecting the specimen, then measuring it, as shown in Figure 4-7. Then the student inserts the specimen into the machine, sets test conditions, and applies load to the specimen until the “necking” appears, see Figure 4-8. After that the size of the broken specimen is measured and the report can be filled in.

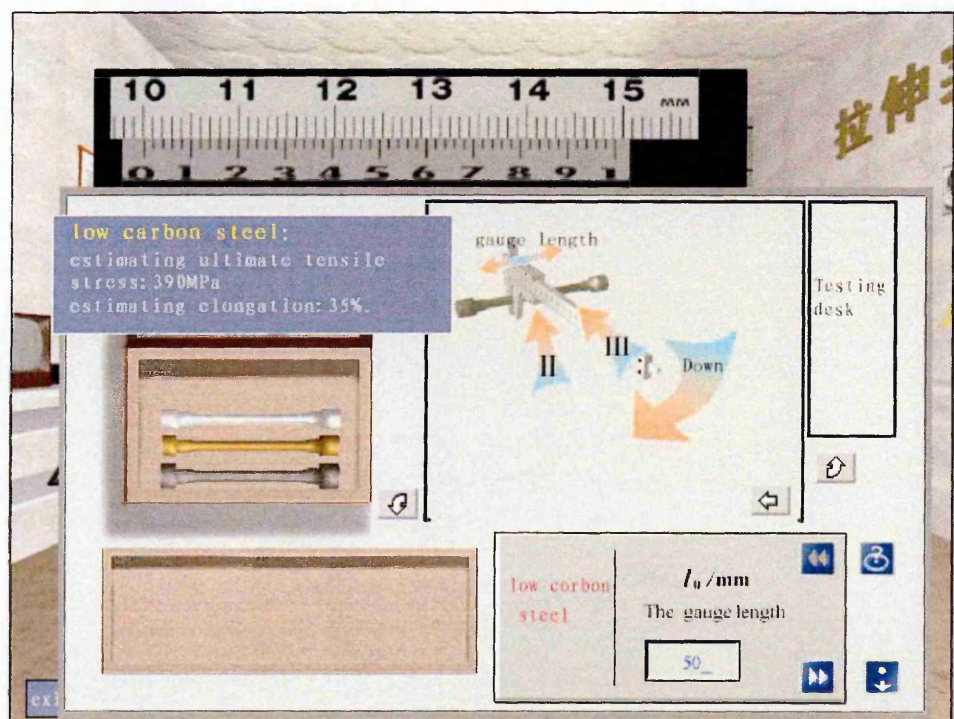


Figure 4-7 Size of tensile specimen measuring

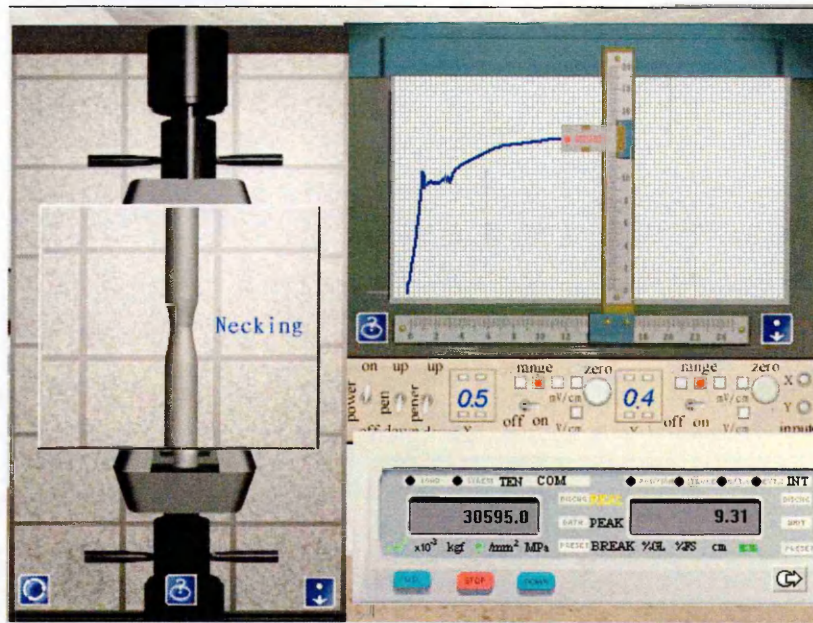


Figure 4-8 An important phenomenon—necking appearing during tensile test

The Virtual Laboratory in Materials Science was developed from 1997 to 1999. This software was packaged into a CD-ROM. The CD-ROM was attached to the text book titled *Applied Mechanics* without additional fee for engineering students in the CRTVU. Part of the courseware was translated into English for the research in 2000. During the research, the software was installed in multi-media computers with the Windows 98 operating system or a higher version depending on the research setting. The Chinese participants used the Chinese courseware and the English participants used the English courseware as described next in Chapter 5.

Chapter 5 Methodology

5.1 Overall design of the evaluation

In Chapter 2, the characteristics of distance education that are to do with quasi-permanent separation of teacher and learner, teaching-learning based on multimedia resources, and mostly individual learning were discussed. It was shown how technologies especially ICT and technical media can play an important role in distance education. For engineering education, laboratory work is not only a basic requirement for engineers but it is also a valuable way of improving understanding. A virtual laboratory in a VR or VE can offer an opportunity to make up for the lack of laboratory work in a distance engineering learning programme. In Chapter 3, two basic experiments, tensile and torsion test, were introduced and the Virtual Laboratory for tensile testing that was designed and developed, was described in Chapter 4.

There were over thirty thousands students of CRTVUs who used the Virtual Laboratory in Materials Science from 1999 to 2003 replacing the real testing or as supplementary material for preparatory lessons before taking the real testing. To meet individual learning needs, the Virtual Laboratory in Materials Science was a significant cost saving and had real educational worth.

However, was the courseware useful? Did the students learn from using the

courseware? Did they enjoy using the courseware? What aspects of the design of the courseware were successful, and what were not? These questions could be answered by a carefully designed evaluation.

The evaluation approaches discussed in Chapter 2, for the usability evaluation of VR and VEs, cover formative and summative evaluation. Formative evaluation is “an observational, empirical evaluation method that assesses user interaction by iteratively placing representative users in task-based scenarios in order to identify usability problems, as well as to assess the design’s ability to support user exploration, learning, and task performance.” (Bowman et al, 2002) Summative evaluation is “a statistical comparison of two or more configurations of user interface designs, user interface components, and/or user ITs. As with formative evaluation, representative users perform task scenarios as evaluators and collect both qualitative and quantitative data.” (Bowman et al, 2002)

For evaluation, a pretest-posttest approach can be used that “focuses on comparisons of student performance before and after the learning has been undertaken” (Calder, 2001) as was outlined in Chapter 2.

Based on study of the preceding chapters, an integrated framework for evaluation including pretest—posttest comparison was used to evaluate the Virtual Laboratory in Materials Science that focuses on comparisons of

student performance before and after the tensile experiment has been undertaken. The integrated framework of evaluation (shown below in figure 5-1) included control groups and treatment groups.

The study used two treatment groups that worked with the Virtual Laboratory in Materials Science and two control groups that worked with a real testing machine—a Hounsfield Tensometer (see Chapter 3, page 44). Engineering students at the UKOU and CRTVUs were involved in two groups in which students were randomly assigned to the groups. As mentioned by Calder (2001), the methodological drawbacks of pretest-posttest comparison approach may be such as the possible effects of external events, extra help, and the effect on the group of constant testing. So the research invited students to come to the research setting to carry out the tensile experiment one by one with no chance to communicate with the others about their experiences. Identical measures were used to assess the learning outcomes of each group so that the same real testing machine, the Hounsfield, used by the OU students in UK was flown to China for CRTVUs students. To obtain valid and reliable data all participants were engineering students studying with the UKOU and CRTVUs, who had not undertaken tensile experiments before they came to the research.

The main research processes were:

- 1) Pretest: Before undertaking the tensile test with the courseware or the real, machine students answered some questions about their basic

understanding of tensile experiments and the properties of typical materials.

- 2) Task: Students carried out the tensile experiment.
- 3) Posttest: After the tensile test students answered the same questions as in the pretest and additional questions about their attitude toward the experiments.
- 4) Data collection and analysis: Quantitative and qualitative data collection and analysis.
- 5) Comparison: Comparison of pretest and posttest data.

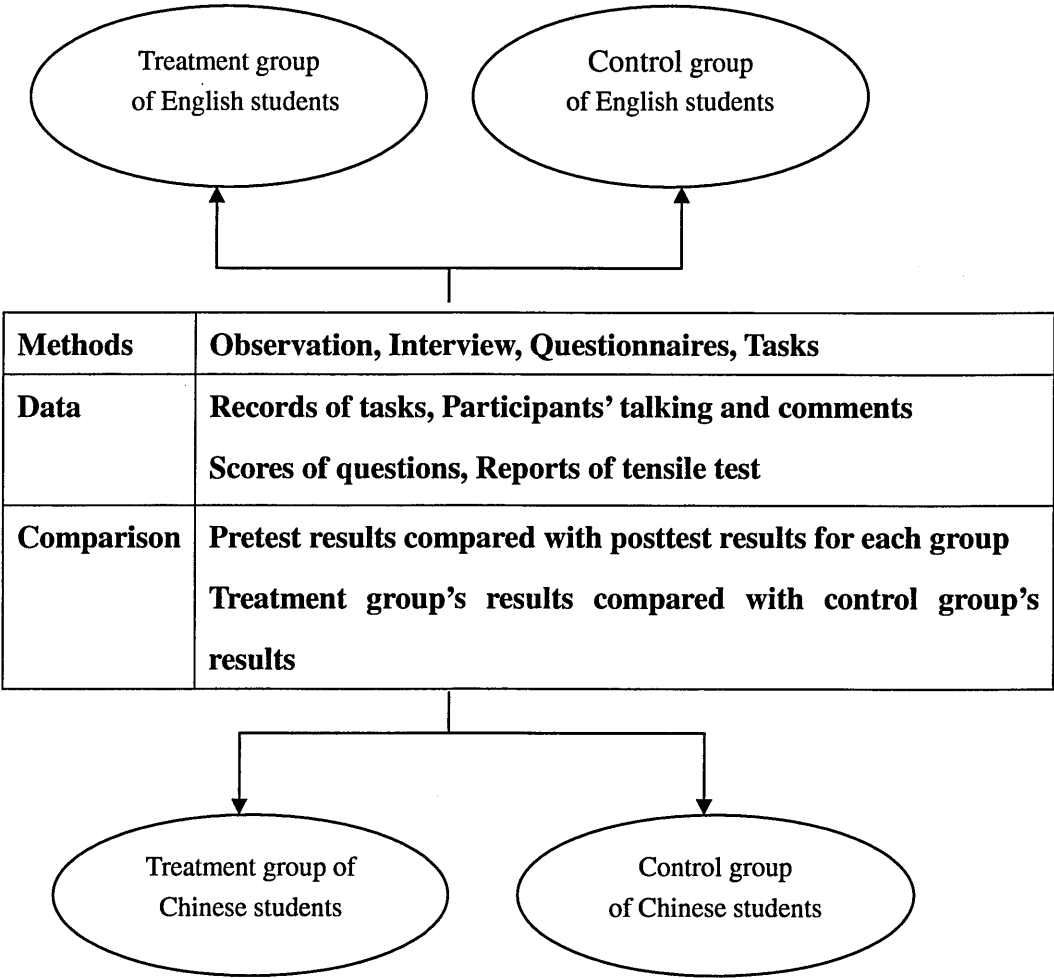


Figure 5-1 Framework of evaluation for the courseware

5.2 Design of the tasks

The purpose of the tasks was to explore the degree of improvement in the students' understanding of basic knowledge of materials engineering and improvement in experiment skills. After the pretest students could find out what he/she understood about the tensile test and what problems there were in relation to the learning content. Then he/she would rethink the problem while carrying out the tensile test. For example, the question "Suppose you are carrying out a tensile test for a low carbon steel specimen, do you know what would happen to the specimen if it was extended beyond the maximum load in a force-extension graph?" This could make students pay attention to the "necking" that happened to the specimen during the experiment. Further, students would find that some permanent (plastic) deformation in the specimen with "necking" occurred as the extension was increased and the force fell. Therefore, in the posttest, students would re-check the answer to the question he/she chose in the pretest. That would help students better understand certain characteristics of typical materials.

- Research setting: There were two sectors in the room. One part was for the treatment group where there was a lap-top computer installed with English and Chinese courseware—the Virtual Laboratory in Materials Science. Another part was for the control group where there was a real testing machine—the Hounsfield Tensometer.

- Instructions for the experiment: Because no participant had taken the tensile test before, instructions for the experiment would be provided to every subject. For example, the instructions for the tensile test by the virtual testing machine were as below.

Objectives:

Through a tensile test for low carbon steel specimen, obtain the following data and view basic mechanics phenomena during the test.

- 1) Original dimensions of specimen (including gauge length, diameter of cross-section of specimen).
- 2) The values of force and extension corresponding to the load at yield point, and the maximum load
- 3) The dimensions of the specimen after fracture (including gauge length, diameter of the cross-section near the broken point)
- 4) Yield stress
- 5) UTS
- 6) % Elongation
- 7) % Reduction in area

Procedure:

Step 1 Click on “Tensile test” icon

Step 2 Click “specimen” icon and then select the upper specimen (low carbon steel) for testing. Drag the specimen onto the measurement area.

Step 3 Now measure the specimen dimensions by means of the calipers.

Take two measurements (in mutual vertical directions) of one cross-sectional area (e.g. Section I) and type your results into the data block.

Step 4 Click “OK” button or drag the specimen to testing desk, then click on close button.

- Discussion: After reading the instructions for the experiment there was ten to twenty minutes discussion during which the researcher and the participants talked to each other about details of the tests. That was important for making sure that participants understood how to conduct the experiments.
- Participants: Firstly thirteen UKOU engineering students were invited to be involved in the research at the UKOU campus and later thirty-eight students engaged in a summer school in Manchester. CRTVU engineering students took part in the session at Tianjin RTVU that is a branch of the CRTVU. Thus fifty-one UKOU students and sixty-one CRTVU students were involved. The UKOU and CRTVU participants were randomly divided into a treatment group and a control group respectively. The study used two treatment groups that worked with the Virtual Laboratory in Materials Science and two control groups that worked with the real testing machine—the Hounsfield Tensometer.

- The experimental test reports (appendix 3): To evaluate the benefits of the tensile test in terms of the experiment procedure and laboratory skills, besides the questions answered by students in the pretest and the posttest, the test reports were finished by the two groups of students, one who worked with the virtual testing instrument and the other who worked with the real testing machine. The students needed to measure the dimensions of the specimen, go to the reckoner (Appendix 4) in the computer, calculate tensile property data and fill in the report form.

5.3 Design of the questionnaire

The research used a questionnaire (Appendix 1 and 2) that consisted of an information sheet and the questionnaire itself. As mentioned in Chapter 2, the purpose of the CAL evaluation was “to evaluate the effectiveness and quality of CAL, whilst at the same time, investigating the educational situation as a whole and focusing on the learners.” (Jones et al, 1996, Draper et al, 1998) The information sheet contained participants’ personal information such as age, gender, educational level and ICTs background such as experience of computers. To assess the extent of students’ experience with computers six single or multiple choice format questions were asked. For example,

How often would you say you use a computer?

- A. Every day
- B. Every 2-3 days
- C. Once a week
- D. Once a month
- E. Less than once a month
- F. Never

How skilled do you think you are at using a computer?

- A. Expert
- B. Advanced
- C. Competent
- D. Novice
- E. Never used one

There were various question formats used in the questionnaire to investigate learning outcomes through the test and allow students to give their opinion about the tensile test. For instance, using a closed question format for the question,

How could you get the graph showed above?

- A. It can be plotted by a recorder automatically or manually from tensile test data.
- B. It can be plotted by calculation from Hooke's law.
- C. It could be plotted from elastic and plastic materials properties.
- D. Do not know.

Another question format was matching questions such as,

What is the sequence of steps in a tensile test? (Match an appropriate sentence to each step)

Step one

Measure the specimen's broken sizes

Step two

Record the data in test report

Step three

Set test conditions

Step four

Measure the specimen's original sizes

Step five

Load the specimen

Step six

Fix the specimen in the test machine

As described in Chapter 2, "Virtual technologies are new computer technologies that offer VR simulations and VEs in which to learn." To investigate students' feelings and attitudes toward using the VR-based courseware, closed question formats and open question formats were used in the questionnaire. For instance, closed questions like,

Did you like using the virtual testing laboratory?

A Liked it very much

B Liked it

C Liked it little

D Did not like

Open questions were asked to gain students' opinion about the experiments.

Which sections of the tensile test did you find difficult or unclear?

What are your suggestions for improvements?

Therefore, the questionnaire was made up of two parts.

- The first part was the pretest that included six questions about basic knowledge of tensile experiments. Some questions were usually easily answered if using the textbook. For example,

Question 1: Below are illustrations of three different tests. Which one of these illustrations shows a tensile test?

Some of the questions were a little difficult for students when based on knowledge of tensile testing. These two were about the idiographic phenomena and manipulation of a tensile test. For instance,

Question 5: Suppose you are carrying out a tensile test for a low carbon steel specimen. Do you know what would happen to the specimen when it was extended beyond the maximum load in a force-extension graph?

- The second part was the posttest including Section A and Section B. Section A asked participants to answer the same six questions as those in the first part after they had carried out the tensile experiment. These six questions aimed to compare the degree of improvement in knowledge of tensile testing. There were some additional questions in Section B to gain students' attitudes toward tensile testing using the courseware or a real machine.

5.4 Scoring and data analysis of the research

Li discussed the Likert scale ranging used to obtain subjects' attitudes

toward the Internet in her Ph.D. degree thesis

“There are debates about the issue of whether one should use an even point Likert scale (2 point, 4 point, 6 point) or an odd point Likert scale to obtain subjects’ attitudes.” Her study “used an even (6-point format of strongly disagree, disagree, mildly disagree, mildly agree, agree, strongly agree) rather than an odd number of response alternatives because the researcher wanted to “force” subjects to agree or disagree with each item in order to get a better spread of scale scores.” (Li, 2002)

For similar reasons, the current research used a 4-point Likert scale of ‘liked it very much, liked it, liked it little, did not like’ to gain students’ general attitudes to the experiments with courseware and a real machine.

A measure of ‘Correctness proportion’ was used to classify the answers to the six questions in the pretest and the posttest about basic knowledge of tensile testing. There were four formats of correctness proportion which were ‘correct answer, partly correct answer (when there was more than one correct answer), wrong answer and do not know’. For example,

Using which instrument could you measure the dimensions of the specimen accurately for a tensile test?

- a) A ruler..... Wrong answer
- b) Vernier calipers..... Correct answer
- c) Micrometer..... Wrong answer
- d) Tape measure..... Wrong answer
- e) Do not know

Answer b was correct but choosing answer a or c was partly correct as long as answer b was chosen as well.

The proportion of correctness is presented in Chapter 6 in graphical form for each group. Direct comparison of correctness in the pretest and the posttest was performed on each question within each group and between the treatment groups and control groups. Some commentary on the comparative outcomes of evaluating the different groups is also provided in Chapter 6.

Statistical analyses were performed using SPSS (Statistical Program for Social Sciences) to attempt to establish statistical significance and compare the different groups in Chapter 7. The answers to six questions in the pretest and the posttest were allocated numerical values from 0 to 4.

As discussed above, the degree of difficulty of each of the six questions was quite different. Hence the six questions got different scores. For example, Question 1 was easy to answer and so a correct answer was scored 1, a wrong answer was scored 0. Question 3 was a little bit more difficult than question 1 so a correct answer was scored 2, a partly correct answer was scored 1 and a wrong answer was scored 0. The answers to the six questions were scored as in table 1.

Variables were defined in SPSS to analyse the data.

The variable “PRESUM” denoted the mean for the sum of pretest question scores.

The variable “PROSUM” was the mean for the sum of posttest question scores.

The variable “report” was the mean of scores for the experiment report. Its value was 2 for a correct report, 1 for partly correct and 0 for an inaccurate report. The scoring of the experimental report is also shown in table 1.

Question	Answer	Score
1	Correct	1
	Partly correct	0
	Wrong	0
2	Correct	1
	Partly correct	0
	Wrong	0
3	Correct	2
	Partly correct	1
	Wrong	0
4	Correct	2

	Partly correct	1
	Wrong	0
5	Correct	4
	Partly correct	2
	Wrong	0
6	Correct	2
	Partly correct	1
	Wrong	0
Report	Correct	2
	Partly correct	1
	Wrong	0

Table 1 The scoring of students' answers and the reports

Standard statistical procedures were used to analyze the data for comparison within and between control groups and treatment groups.

A Paired-Samples T Test was used to compare the means of the two variables PRESUM and PROSUM for each of the four groups. It computed the differences between values of the two variables for each case and tested whether the average differed from 0.

5.5 Observation of tasks

Participants were observed while they worked with the courseware and the real machine. The researcher played both observer and tutor roles in the observation setting so that participants could ask for help if they were in difficulty in order to make them feel comfortable and relaxed.

Participants were asked to conduct the tensile experiment following the

instructions. The aim of this task was to investigate students' experimental skill by using courseware and the real machine. In the middle of the tensile test necking appeared in the specimen. Whether students paid attention to this phenomenon was observed. The aim of this activity was to find the influence of a prompt on the computer screen. The record made of observations included details of how students undertook the experiments, how they found the icons and how happy they were with the virtual experiment environment the courseware offered. To assess the two different instruction models that are described in Chapter 4 (page 54), the students in the treatment groups were asked to conduct a torsion experiment as a check test.

5.6 Design of interview

The research used open-ended questions in standardized interview schedules because "uncoded questions allow the researcher to search the full range of responses obtained before reducing replies to a set of categories, and the 'translation' of replies to coded categories can be done by the researcher in the office rather than by the interviewer in the field" (Sapsford et al, 1996). For example,

Which sections of the software did you find difficult or unclear in the program?

How was the tensile test?

The aim of the interview was to investigate students' attitudes and comments toward the courseware in more detail. So the participants for the interviews consisted of a total of 33 Chinese and British engineering students from treatment groups who worked with the courseware. 17 OU students (3 female, 15 male) and 16 CRTVU students (5 female, 11 male) were recruited when they took part in the pretest and the posttest and expressed an interest in taking part in the interviews.

Chapter 6 Data from the research

In Chapter 5, the overall approach to conducting the evaluation was set out based around a pretest-posttest methodology as developed by Calder (2001). The questions posed were set out there as were the qualitative evaluation questions used to establish the subjects' views on the measurement methods they used. In this chapter, the data obtained from the evaluation are presented in graphical form. Some commentary on the comparative outcomes of evaluating the different groups is provided but an in-depth discussion of the data is presented in Chapter 7.

6.1 General information about participants

The participants for the research consisted of a total of 112 Chinese and British engineering students (Table 2).

Subject	Condition	Gender	Age
English	Hounsfield: 23	Male: 21 Female: 2	Mean: 33.9
	Software: 28	Male: 26 Female: 2	Mean: 35.8
Total	51	Male: 47 Female: 4	Mean: 34.9
Subject	Condition	Gender	Age
Chinese	Hounsfield 31	Male: 17 Female: 14	Mean: 20.5
	Software 30	Male: 21 Female: 8	Mean: 20.0
Total	61	Male: 38 Female: 22	Mean: 20.3

Table 2 General information about participants

The mean age of the UKOU students was 34.9 years and 20.3 years for CRTVU students.

The following five questions aimed to establish some background information about the students.

1. What educational background do you have?

2. Which computer operating systems have you used?

3. Which types of computer packages have you used?

4. How often would you say you use a computer?

5. How skilled do you think you are at using a computer?

Statistical charts of the resulting data are shown below (Figure 6-1 to 6-6).

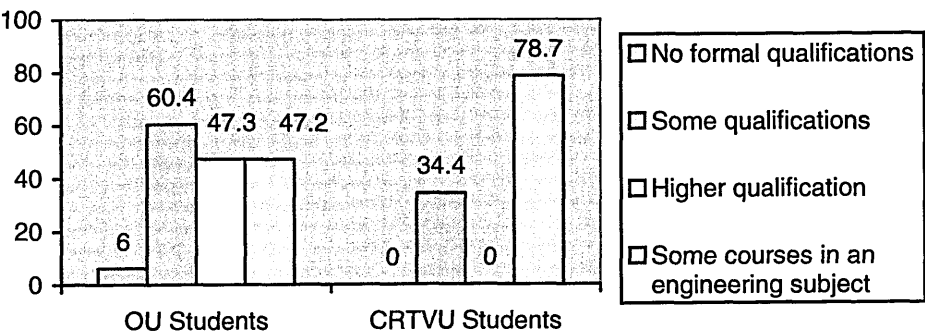


Figure 6-1 Educational background

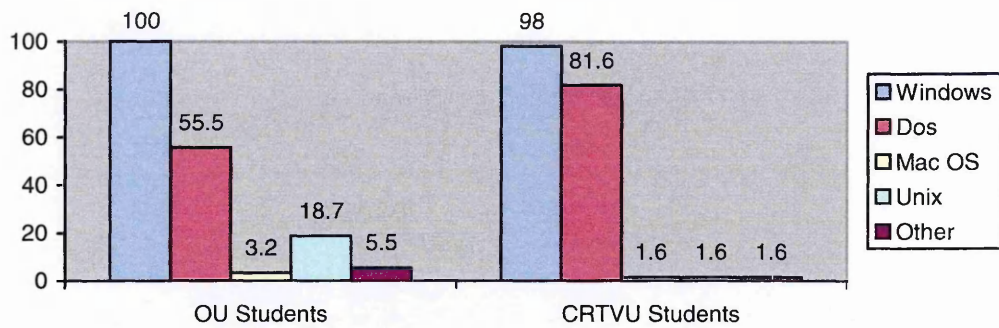


Figure 6-2 Used operating systems

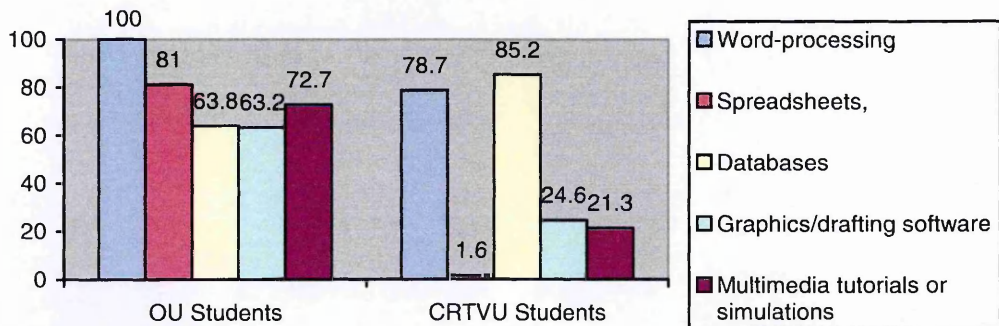


Figure 6-3 Used computer packages

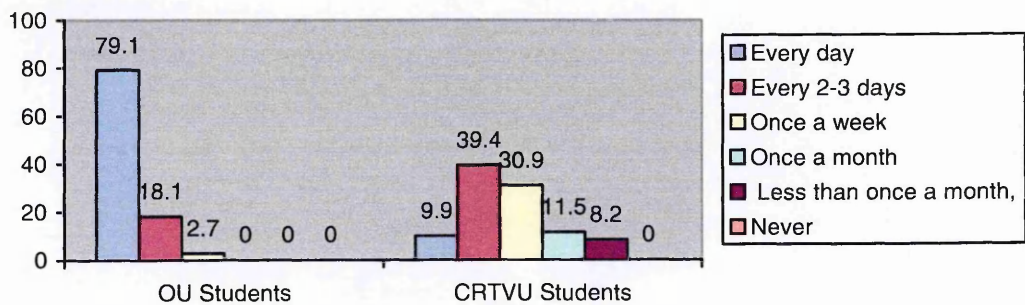


Figure 6-4 Frequency of computer use

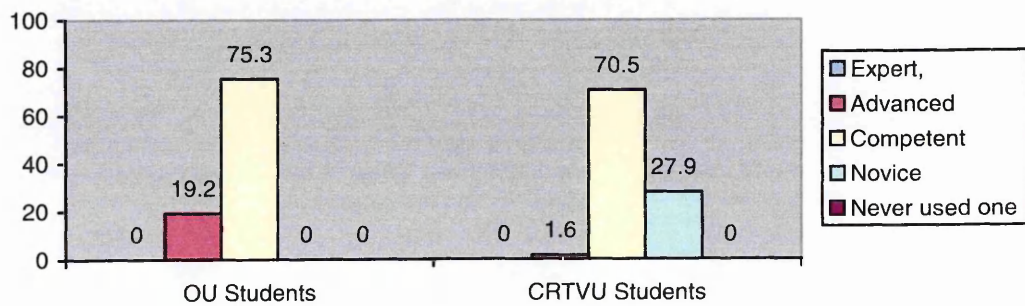


Figure 6-5 Proficiency degree in using computer

Nearly a half of the UKOU students (the rate was 47.3%) had a higher qualification. This was much higher than the rate for CRTVU students.

With regard to computing experience, Windows was the most popular operating system (100% UKOU students and 98% CRTVU students used it) and DOS was the second.

100% of UKOU participants and over 78% of CRTVU participants had used Microsoft Word and 81% of UKOU participants used spreadsheets but no Chinese participant had used them, see Figure 6-3. When comparing Figure 6-4 and 6-5, a correlation can be seen between the level of confidence of the students in using a computer and the frequency with which they use one. Over 97% of UKOU participants used a computer every 2-3 days or more frequently and nearly 94% of them said they were competent in using a computer or better. Just over 49% of CRTVU participants used a computer in the same period, and only about 72% of them felt they were competent or better.

6.2 Correctness proportion of questions

Six questions about basic knowledge of tensile experiments (see box below) were asked in the pretest and posttest to assess students' improvement in understanding of the tensile experiment and properties of typical materials before and after undertaking the tensile test with the courseware or the real machine (see Chapter 5, pages 68–69).

Q1: Below are illustrations of three different tests. Which one of these illustrations shows a tensile test?

Q2: Using which instrument could you measure the dimensions of the specimen accurately for a tensile test?

Q3: What does the graph below show?

Q4: How could you get the graph showed above?

Q5: Suppose you are carrying out a tensile test for a low carbon steel specimen. Do you know what would happen to the specimen when it is extended beyond the maximum load in a force-extension graph?

Q6: What is the sequence of main steps in a tensile test? (Match an appropriate sentence to each step)

The percentage of the students who answered the six questions ranging from a correct answer to not knowing the answer is shown in Table 3 for each group before and after the students carried out the tensile test.

Subject	Condition	Effective sample	Invalid samples
English	Hounsfield	23	0
	Software	28	0
Total	51	51	0
Subject	Condition	Effective sample	Invalid samples
Chinese	Hounsfield	30	1
	Software	30	0
Total	61	60	1

Table 3 Numbers of effective samples

There were four groups involved in the pretest and posttest (See Chapter 5, page 64). The results obtained for each group in both pretest and posttest are

shown graphically in the next two sections.

6.2.1 Correctness of questions in pretest

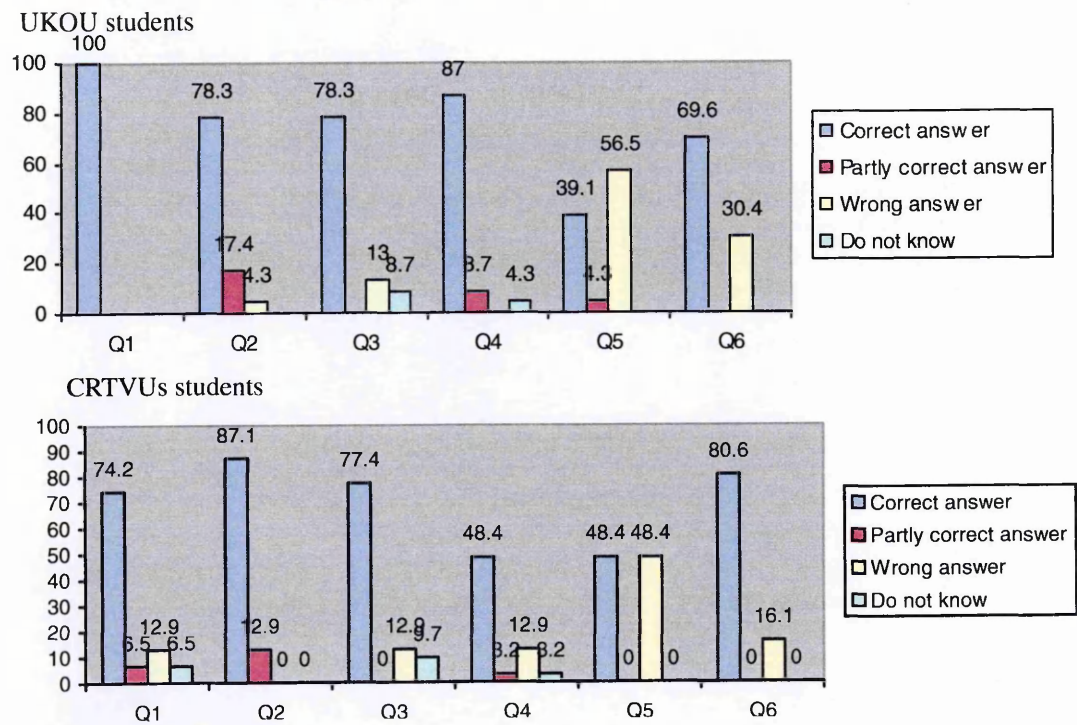


Figure 6-6 Pretest questions for control groups

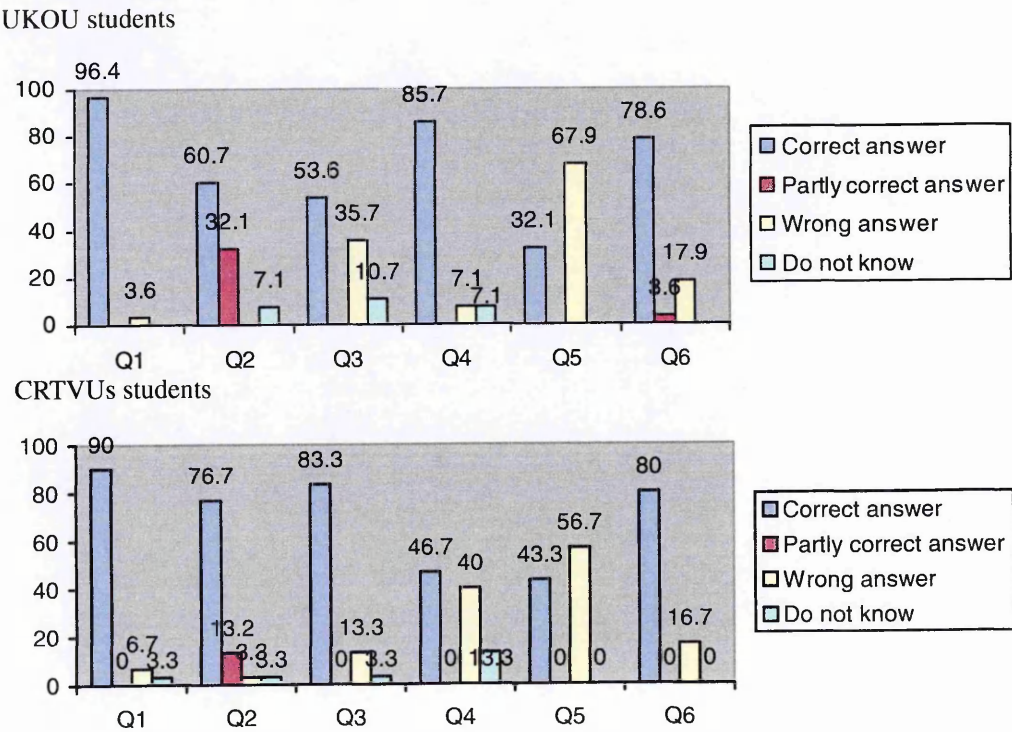


Figure 6-7 Pretest questions for treatment groups

6.2.2 Correctness of posttest questions

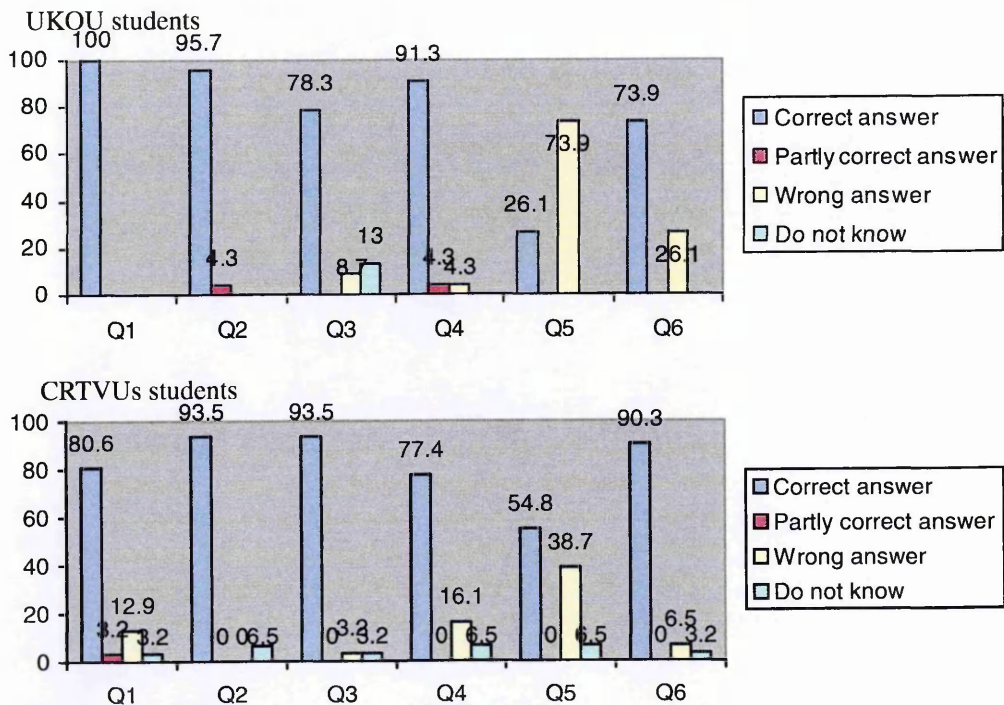


Figure 6-8 Posttest questions for control groups

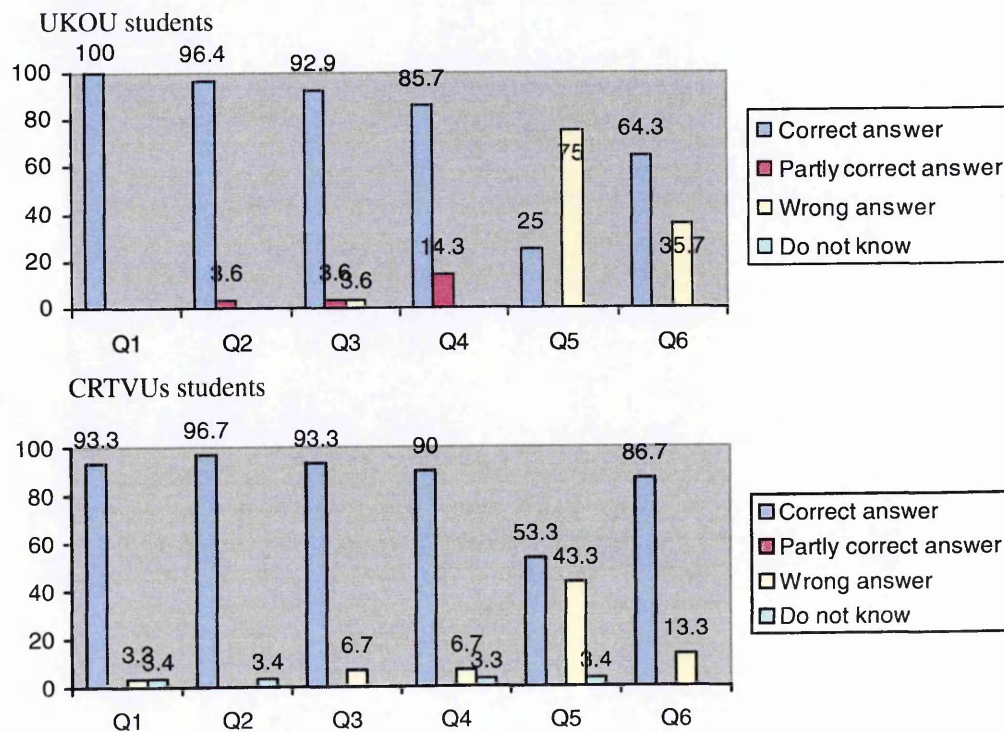


Figure 6-9 Posttest questions for treatment groups

For the CRTVU student group using the Hounsfield, the correctness rate for

question 1 rose from just over 74% to nearly 80%. The answer for question 2 improved from nearly 87% to over 93%. For question 3 it improved from just over 77% to nearly 93%. For question 4 it improved from about 48% to over 77%. For question 5 it improved from just over 48% to nearly 54%. For question 6 it improved from about 80% to over 90%. An average improvement rate of nearly 12% was seen in the correctness rate through all the questions, among which questions 3 and 4 enjoyed the biggest improvement at some 16% and 29% respectively.

For the UKOU student group using the Hounsfield, the correctness rate for question 1 was 100% (before and after testing). The rate for question 2 improved from about 78% to nearly 95%. For question 3 it was a constant 78%. For question 4 it increased from 87% to 91%. For question 5 it dropped down from 39% to 26%, a reduction of 13 percentage points. For question 6 it was slightly improved from 69% to about 73%.

For the CRTVU student group using courseware, the Virtual Laboratory in Materials Science, the correctness proportion for question 1 rose from 90% to over 93%. The rate for question 2 improved from slightly over 76% to nearly 96%. For question 3 it improved from about 83% to over 93%. For question 4 it improved from just over 46% to 90%. For question 5 it improved from just over 43% to about 53%. For question 6 it improved from 80% to nearly 87%.

For the UKOU student group using courseware, the correctness rate for question 1 was slightly increased from nearly 96 to 100%. The rate for question 2 improved from 60% to about 96%. For question 3 it rose from approximate 53% to 92%. For question 4 it was constant nearly 85%. For question 5 it dropped from 32% to 25% a reduction of 7%. For question 6 it was lower after testing (about 64%) than before (about 78%).

6.3 Students' experimental report of the tensile test

To evaluate the benefits of the tensile test in terms of the experimental procedure and laboratory skills, besides the questions answered by students in the pretest and the posttest, the test reports were finished by the two groups of students, one who worked with the virtual testing instrument and the other who worked with the real testing machine. (See Chapter 5, pages 68—69) The percentage of students who filled out the report ranging from correct to wrong is shown in Figure 6-10 for each group after the students carried out the tensile test.

The correctness proportion of the test report for UKOU participants (Hounsfield over 72% and courseware 100%) was higher than that of CRTVU participants (Hounsfield just over 51% and courseware 50%).

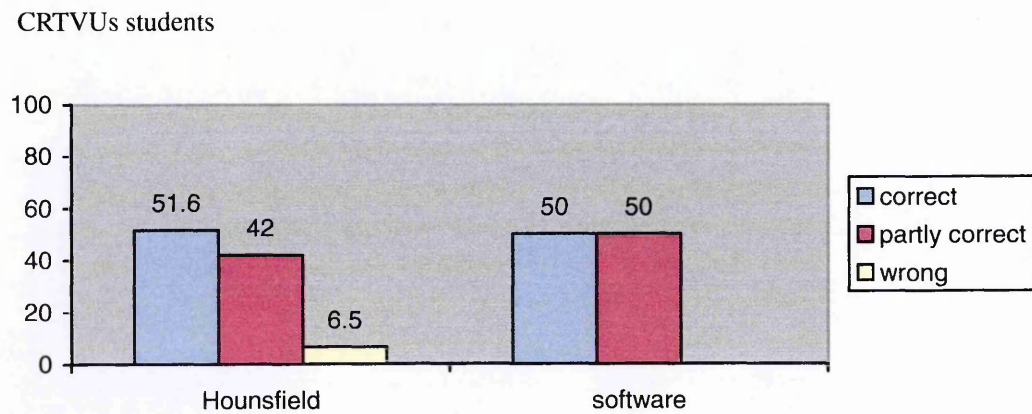
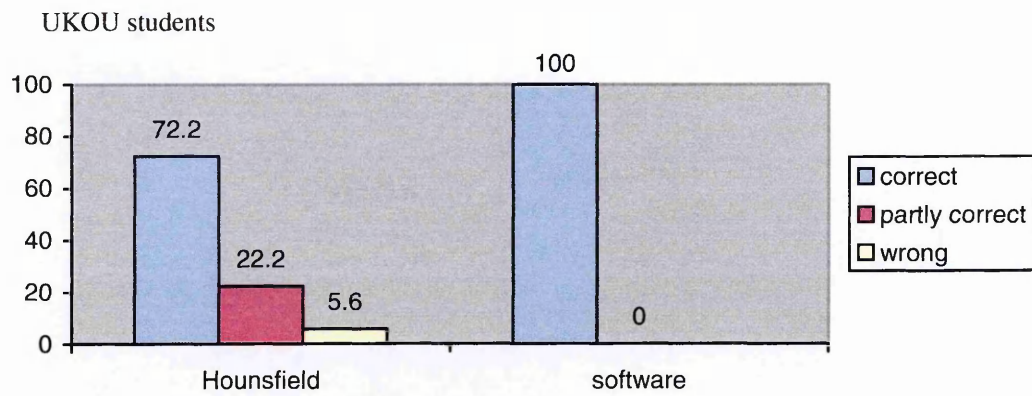


Figure 6-10 Students' report of tensile test

6.4 Students' response to the experiments

6.4.1 Students' response to the real experiment

There were six additional questions in Section B to be asked of the control groups. The findings are shown in Figure 6-11 to 6-16 below.

Did you like using Hounsfield Tensometer to do tensile test?

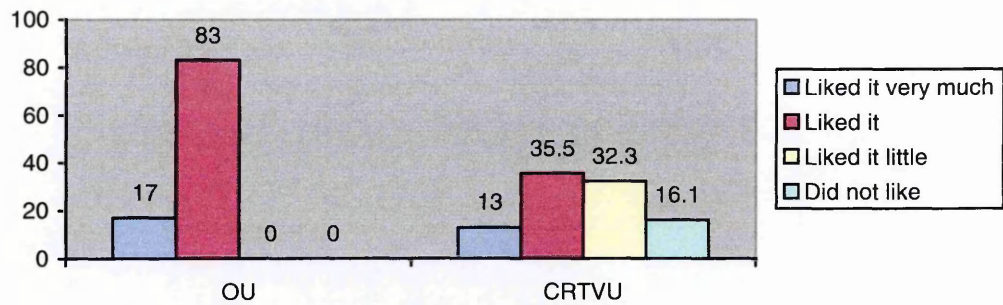


Figure 6-11 Attitudes toward using Hounsfield

How interesting was the tensile test?

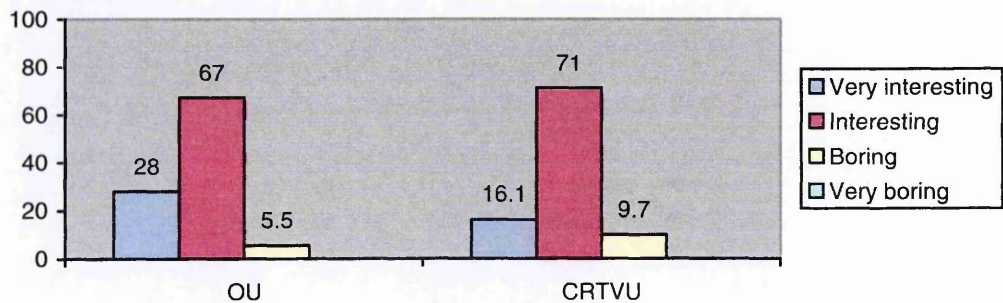


Figure 6-12 Attitudes toward tensile test

Was Hounsfield Tensometer easy to use?

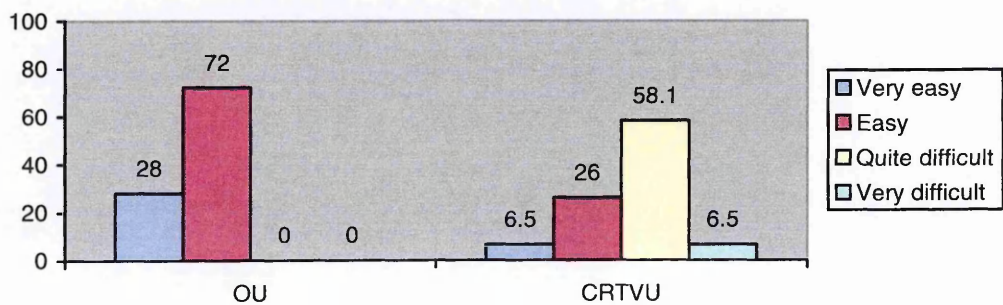


Figure 6-13 Usability of Hounsfield

Which sections of the tensile test did you find difficult or unclear.

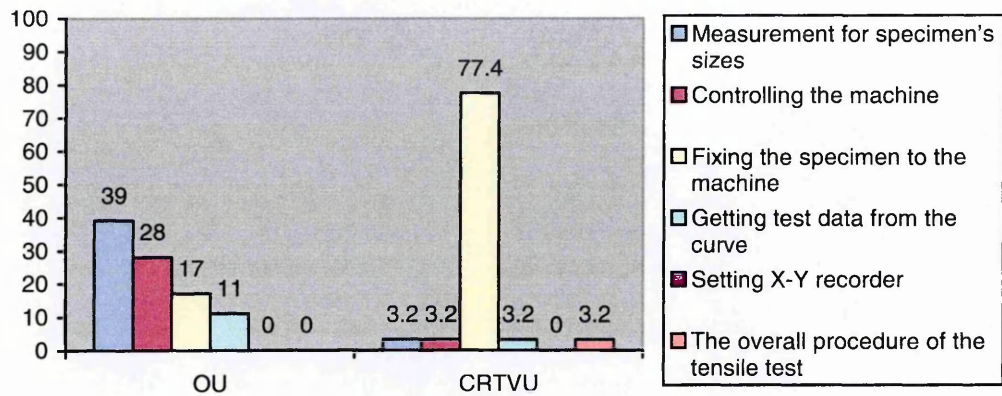


Figure 6-14 Difficult or unclear sections of the tensile test

Do you think your knowledge and skills of tensile test have improved by using Hounsfield Tensometer?

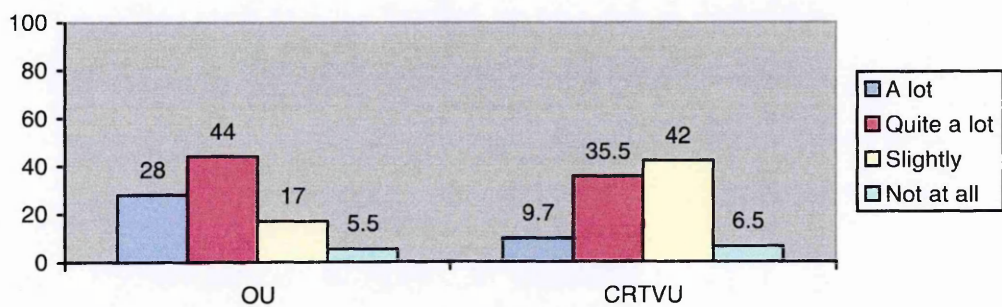


Figure 6-15 Knowledge and skills improved

If you got 'stuck' at any point (due to a difficulty or unclear instructions), how did you get yourself 'unstuck'?

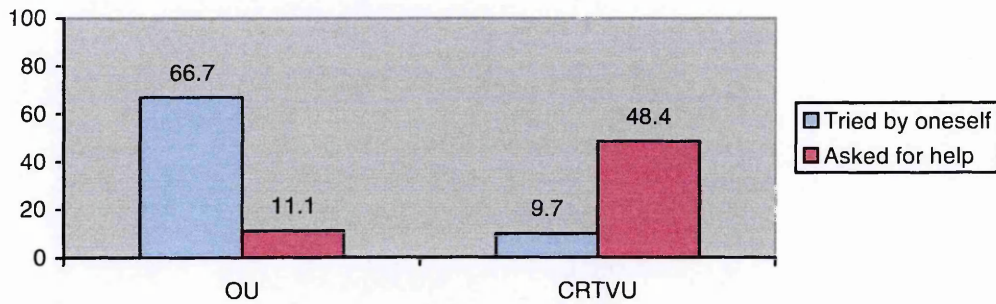


Figure 6-16 Ways of getting 'unstuck'

6.4.2 Students' response to the virtual experiment

For the treatment groups, eight additional questions from Section B were asked in the posttest. Students' attitudes toward the courseware are shown in Figures 6-17 to 6-25.

Did you like using the virtual testing laboratory?

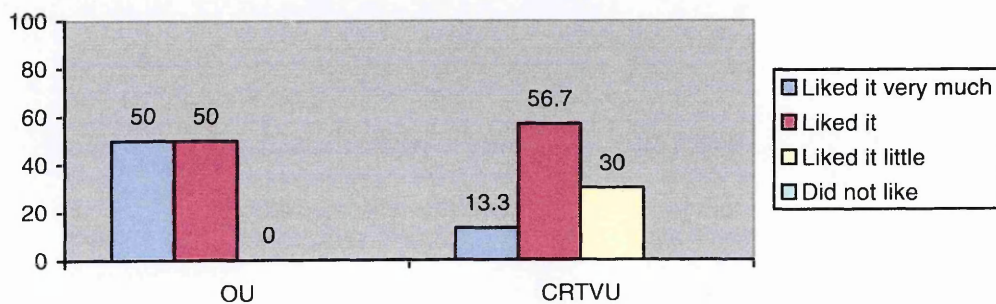


Figure 6-17 Attitudes toward using the virtual testing laboratory

Was the virtual testing laboratory easy to use?

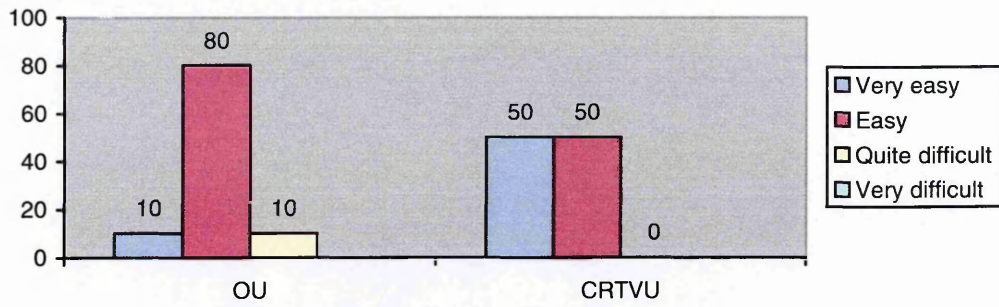


Figure 6-18 Usability of the virtual testing laboratory

Do you think your knowledge and skills of tensile and torsion tests have improved by using the virtual testing laboratory?

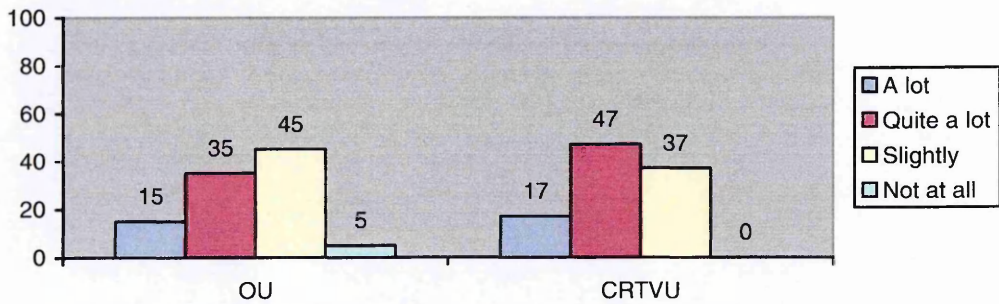


Figure 6-19 Knowledge and skills of tensile test improved

How interesting was the tensile test?

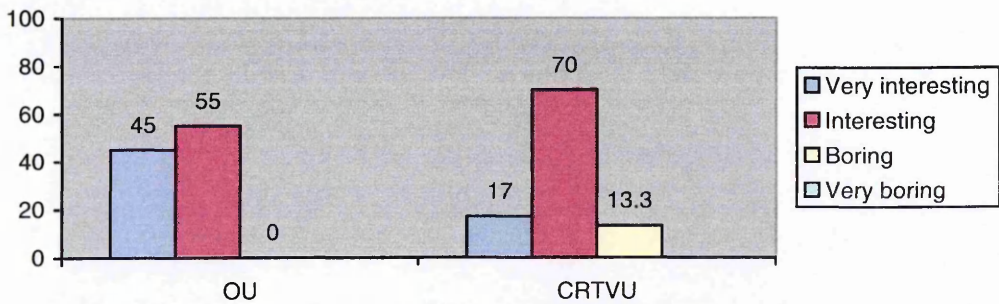


Figure 6-20 Attitudes toward tensile test

To enable us to gauge your thoughts about the tensile test and the torsion test please tick to indicate how strongly you agree with the following statements.

1) Instructions(step by step prompts and Help facility) in torsion test is better than instruction in tensile test (just Help facility).

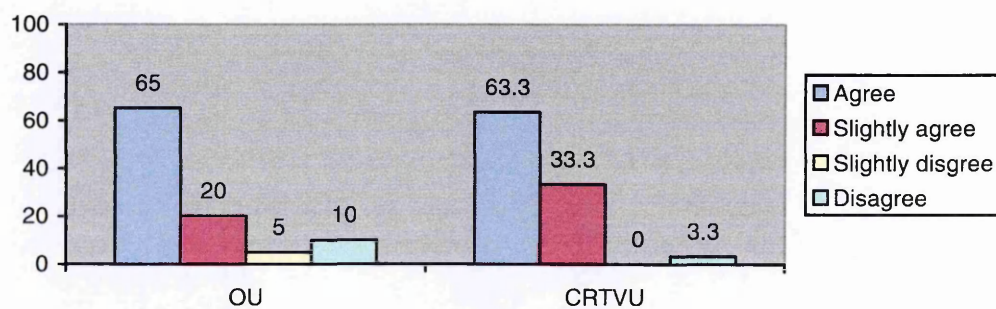


Figure 6-21 Attitudes toward instructions

2) The sounds used during the tensile test make it more interesting than the torsion test

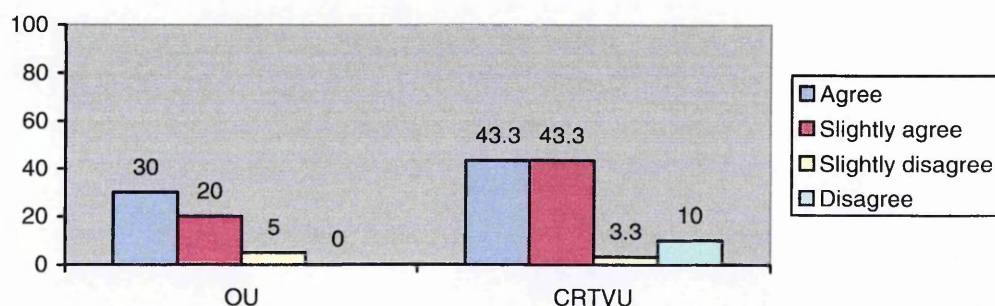


Figure 6-22 Attitudes toward the sounds

Which aspects did you find most helpful in your using the software for testing?

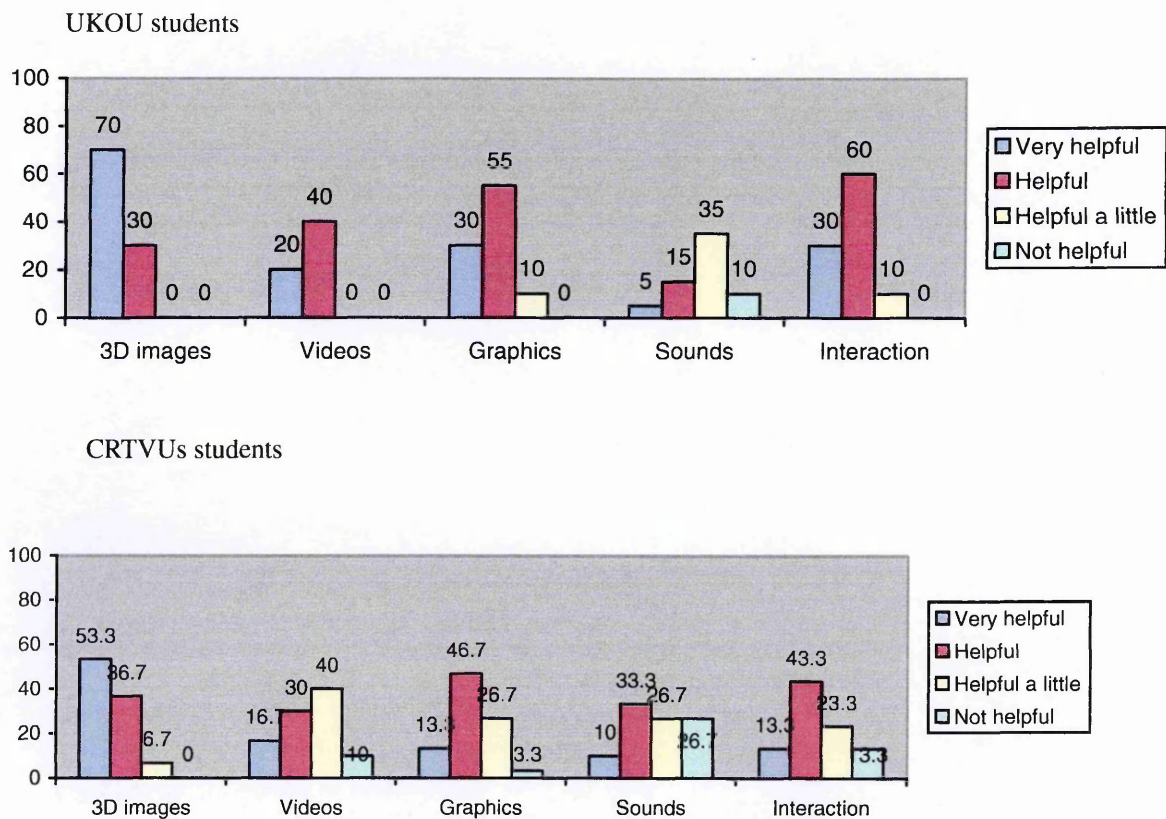


Figure 6-23 Most helpful aspects

Which sections of the software did you find difficult or unclear in the program?

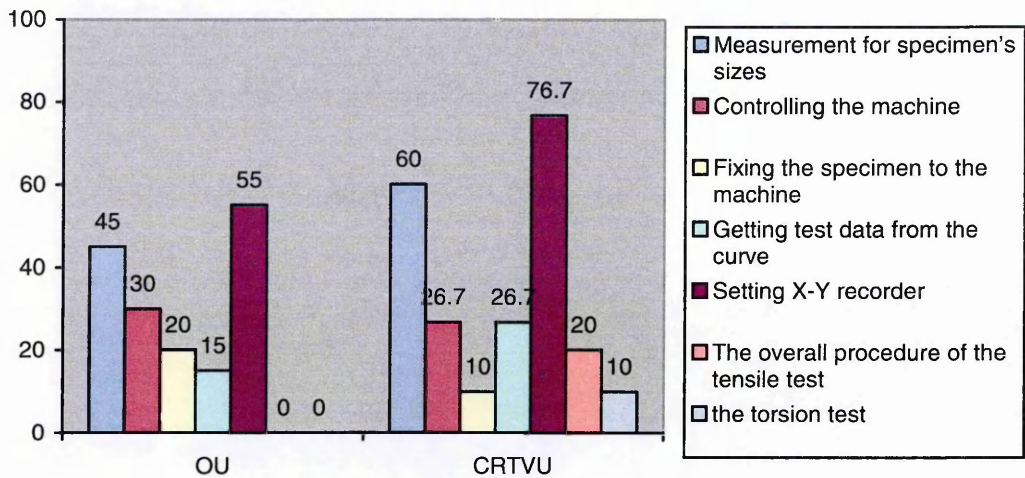


Figure 6-24 Difficult or unclear sections of the software

If you got 'stuck' at any point (due to difficulty or unclear instructions), how did you get yourself 'unstuck'?

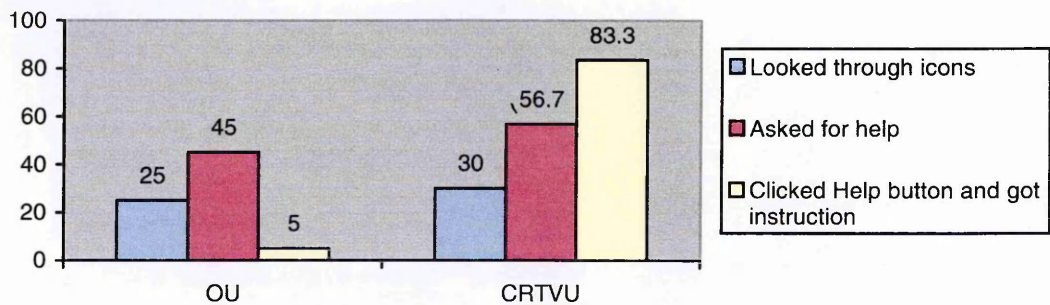


Figure 6-25 Ways of getting 'unstuck'

There were more UKOU participants (50%) who very much liked to do the test using the courseware, while only 17% said they liked the Hounsfield very much. But the difference was not significant for CRTVU participants (courseware users nearly 13% and 13% Hounsfield users). This showed that using multimedia emulation technology in computer software could be an attraction to students depending on their computing skills, as about 79% of

UKOU participants used a computer every day, a much higher frequency than among CRTVU participants where it was below 10%. It was very interesting that there were no UKOU participants who thought that “Hounsfield is quite difficult to use” but over 58% of CRTVU participants thought so. Most students (90% UKOU and 100% CRTVUs students) thought it either very easy or easy to use the courseware. Nearly the same number of participants thought “the courseware is interesting” (55% UKOU and 70% CRTVUs) as those who thought “Hounsfield is interesting” (67% UKOU and 71% CRTVUs).

Chapter 7 Discussion

Discussion in this chapter is focused on the current research questions (see Chapter 5, pages 62—63) based upon the direct statistical data in Chapter 6.

“Was the courseware useful?

“Did the students learn from using the courseware?

“Did they enjoy using the courseware?

“What aspects of the design of the courseware were successful (and what not)?”

In this chapter, the quantitative data and qualitative data are discussed to find out about students’ understanding of tensile testing and experiment skills through using the courseware. Further statistical analyses were performed using SPSS (Statistical Program for Social Sciences) to find some statistical implications and compare the different groups. Standard statistical procedures were used to analyze the data for comparison within and between control groups and treatment groups. (see Chapter 5, pages 72—75)

7.1 Students’ understanding of tensile test and experiment skills

This section focuses on discussion of the first two research questions. “Was the courseware useful? Did the students learn from using the courseware?

The Virtual Laboratory in Materials Science was designed to construct a virtual experiment environment to carry out tensile and torsion experiments whilst teaching the basic properties of some typical engineering materials.

The evaluation pertained to students' understanding of the tensile test and experimental skills which expose aspects of students' explicit and implicit learning.

7.1.1 Basic knowledge of the tensile test

As outlined in the evaluation design in Chapter 5, questions 1 and 2 were about usage of experimental equipment and question 4 was about the process of the experiment. The results presented in Chapter 6 showed that there was an improvement in the performance of the students in these three questions after both the virtual test and the real test. It indicated that the Virtual Laboratory in Materials Science based on non-immersive VR technology can offer a virtual testing environment similar to the real world for students. Furthermore the improvement range by using the courseware was better than that by using the real machine. For example, for question 2, CRTVU students and the UKOU students, the improvement rates 20% and 36% by virtual testing were better than the improvement rates 6% and 17% by real testing. The reason might be that the courseware offered prompt instructions to every virtual image when clicking during testing. It can help students to understand more about the testing machine, experimental equipment and the process of the experiment. The same finding was obtained in the interviews. Most students who were interviewed delivered positive reviews about the role of the courseware in their learning. The following extracts from interviews with students illustrate this conclusion as well.

The Chinese student (subject 47, male 20 years old) talked about his opinions of the experiment using the software:

“形象很生动，有利于学生学习。拉伸实验全过程方便。”

“Very vivid image that is conducive to learning. The entire process of tensile test is convenient.”

Subject 20 (British student, male, 38 years old) said:

“I feel that if I was able to spend a little more time that any problems encountered would have been overcome as the screen labeling was good, it was just a matter of finding it.”

Another British student, subject 17 (Male, 34 years old) expressed his feelings:

“It would take several tests to feel confident in the procedures. Good environment to learn and try.”

These results confirmed that the use of the Virtual Laboratory in Materials Science could make a contribution to students' understanding of tensile testing.

7.1.2 Basic knowledge of tensile properties

The aim of tasks for the evaluation was to explore the degree of improvement

in the students' understanding of basic materials knowledge. Therefore there were two questions, questions 3 and 5, about basic knowledge of tensile properties asked in the pretest and the posttest. Question 3 "What does the graph below show?" was asked to expose aspects of students' explicit learning on basic knowledge of tensile properties. The result from Chapter 6 showed the correctness was improved for both CRTVU students and the OU students using the courseware (see Chapter 6, pages 84—85). It indicated that the courseware was valuable for visualizing materials knowledge by presentation of stretching the specimen in a machine synchronized with plotting a load-extension curve on the computer screen.

As described in Chapter 5, the original design idea of question 5 was to make students pay attention to the "necking" that happened to the specimen during the experiment. Further, students would find that some permanent (plastic) deformation in the specimen with "necking" occurred as the extension was increased and the force fell. Observation of the subjects during the testing suggested most Chinese students' attention was strongly aroused by the enlarged "necking" scene in the computer, described in Chapter 4. Some of them also asked the researcher for more details of the "necking". But most British students did not pay much attention to the "necking" scene and did not ask any questions.

This might be linked to the different backgrounds of Chinese and British

students. CRTVUs participants were very young (the mean age was 20.3) with a little working experience so that they were eager to find the answer to the question from information presented on the screen. They seemed to enjoy multiple-windows presenting relevant information on a computer screen and were interested in the animation scene. They paid attention to what was a correct answer even if needing to ask for help. On the other hand UKOU participants were mostly older with several years of working experience. For the little screen with abundant information, a British student (subject 11, male, 37 years old) suggested “*Bigger screen needed.*” And another British student (subject 12, male, 29 years old) said: “*Differing screens need highlighting to reduce chance of error.*” But UKOU participants were much more independent than CRTVUs participants when they answered questions. They seemed to trust their judgement. Another result from Chapter 6 might support this situation which was that more UKOU participants (72%) than CRTVU participants (about 45%) thought using the Hounsfield could improve their knowledge and skills in tensile testing a lot or quite a lot. But more CRTVU participants (64%) than UKOU participants (50%) thought using the courseware could improve their knowledge and skills in tensile testing a lot or quite a lot.

The results from Chapter 6 showed that the correctness rate was quite low for question 5. The correctness was over 43% for CRTVU students and 32% for UKOU students before testing in software groups. A little improvement up

to over 53% was seen for CRTVU students but decline to 25% was seen for UKOU students after testing. The same thing happened in the real machine groups. The following reason can be suggested for this: the question was about certain materials characteristics of specific materials. To develop the knowledge to be able to attempt such a question would require a lot more practical work doing tests over a range of materials in order to build up mental comparisons. There was not scope within the testing experiments to do lots of comparisons so, in the end, it was an unfair question to set. This kind of implicit learning needs more pre-learning before carrying out the experiment.

This possibility is supported by the students talking in the interview.

Subject 13 (British student, female, 30 years old) said: *“Any problems I had have been with my own lack of knowledge of engineering not the software.”*

Subject 15 (British student, male, 41 years old) suggested: *“It may be better to watch the video before attempting a test.”*

7.1.3 Experiment skills in tensile test

Through the observation, it was seen that all participants completed the tensile test by using the courseware. 100% participants accomplished experimental test reports which were correct or partly correct following the virtual test. This correctness proportion was better than that in the real machine groups. It deserves attention particularly as some of the participants were even novice

users of the computer. This confirmed to a certain extent that the courseware with virtual technology was a satisfactory way of conducting the experiments especially where the emphasis was on verifying scientific properties and theories without more manual operation. Students appraised the courseware as *“It is an excellent alternative for people who cannot get hands on experience.”* (Subject 13, British student, female, 30 years old) Another student said *“The overall procedure of the tensile test is good. To be able to try and see.”* (Subject 3, British student, male, 37 years old)

But with regard to the experimental skills of manual operation, to a certain extent it was hard to operate by clicking with the mouse in this particular non-immersive VR (see Chapter 2, pages 29—30). For example measuring the sample size by using Vernier callipers: the problem in practice was how to use the calliper in the computer. 45% of UKOU students and 60% of CRTVU students thought that measuring the specimen’s size was a difficult section of the software after the virtual test. Another result from Chapter 6 for question 6 might support this conclusion, that the improvement rate of the operating procedure of tensile testing after the virtual test (CRTVU students increased 7%) was lower than the improvement rate after the real test (10%) and the improvement rate declined 14% after virtual testing for the OU students. The same finding came from interviews.

A Chinese subject talked about her opinions of the experimental skills of manual operation with the software.

“我觉得还是直接动手操作比较好，软件可以作为补充。”

“I think it is better to take the experiment by hand and use the software as a supplement.” (subject 49, female, 20 years old)

7.2 Students' attitude toward the courseware

This section focuses on discussion of the two latter research questions. “Did they enjoy using the courseware? “What aspects of the design of the courseware were successful (and what not)?”

As described in Chapter 5, there were some additional questions asked to obtain students' attitude toward the courseware in posttest and in the interview. From the results in Chapter 6, most students (100% of UKOU students and 70% of CRTVU students) said they either liked very much or liked using the courseware to do the test. Within these results, though, 50% of UKOU participants said they liked using the courseware very much but only 13.3% of CRTVU participants said so. This might suggest that using multimedia emulation technology in computer software could be an attraction to students depending on their computing skills, as about 79% of UKOU participants used a computer every day, many more than the 9.9% of CRTVU participants.

Most students (90% of UKOU and 100% of CRTVU students) thought it either very easy or easy to use the courseware, nearly the same number of participants who thought the courseware either very interesting or interesting

(100% UKOU and 87% CRTVU). It was very interesting there were no UKOU participants who thought that “Hounsfield is quite difficult to use” but 58.1% of CRTVU participants thought so. That might also be caused by the difference in participants’ backgrounds discussed above.

The findings from the interview showed students’ feelings towards the courseware in more detail.

A Chinese student (subject 50, male, 21 years old) said:

“挺满意。我对此很感兴趣，希望以后多些这样的课程。”

“Very satisfied. I am very interested in the software. Hope that there are more such lessons.”

Subject 13 (British student, female, 30 years old) said:

“Having never done any testing of this sort I found this program outstanding.”

Another Chinese subject 49 (female, 20 years old) spoke about:

“总体来说软件设计还不错，已经是很大程度上发挥了计算机这个媒体的作用。”

“The whole software design is quite good and gives full scope to the computer.”

It was obvious that academic problems and technical problems came up during learning with the courseware. Students needed different kinds of

assistance if he/she got 'stuck' at any point (due to a difficulty or unclear instructions) during learning with the software. 45% of UKOU students and 56.7% of CRTVU students preferred that they "asked for help". Some participants (20% of UKOU students and 30% of CRTVU students) chose looking through icons for help. 83.3% of CRTVU participants liked to use the help button to get instructions for help. Therefore not only prompt instruction was useful but also the help function was really important in this example of computer-based teaching.

As described in Chapter 4, "there were two different instruction models in the application. One was individual control instruction that allowed students to conduct the experiment on his/her own. Another model was step-by-step control instruction that offered a clear and direct instruction of the process which the students could follow to conduct the experiment." (Chapter 4, page 54) Through observation of the students during the testing, it was found that some participants enjoyed individual control instruction. But others seemed to get 'stuck' in wrong operating steps with the individual control instruction model. For example, a student wanted more instructions when she got stuck following the individual control instruction.

She suggested:

“虚拟实验软件比较生动形象。但有时不易理解，应在操作困难处多讲解一下。”

"The virtual experiment software is quite vivid. But sometimes it is difficult to understand. There should be more explanation of difficult operations."

(Subject 57, female, 20 years old)

A total of 65% of UKOU students and 63.3% of CRTVU students agreed with "instruction with step by step prompts and Help facility was better than just with Help facility". But there were 10% of UKOU students and 3.3% of CRTVU students who did not like instruction with step by step prompts.

Finally some students made a suggestion about the software in the interview.

For example,

“多一点提示。”

"Suggest a few more prompts." (subject 50, Chinese student, male, 21 years old)

"Yield point could stop and be recorded." (Subject 12, British student, male, 29 years old)

And a British student gave his view as:

"I would like to be able to see the fracture face in greater detail." (Subject 19, male, 35 years old)

7.3 Data analysis in use of SPSS

In the preceding discussion some analysis of the results was presented. Qualitative analysis and interpretation was presented using a combination of

the numerical results from the questionnaires and the records of the structured interviews. Next the data from the results were analyzed further using SPSS to find some statistical implications, as described in Chapter 5,

The variable “PRESUM” denoted the mean for the sum of pretest question scores.

The variable “PROSUM” was the mean for the sum of posttest question scores.

The variable “report” was the mean of the scores for the experimental report.

“A Paired-Samples T Test was used to compare the means of the two variables PRESUM and PROSUM for each of the four groups. It computed the differences between values of the two variables for each case and tested whether the average differed from 0.” (Chapter 5, pages 75—76) The number of cases used in the Paired-Samples T test is shown in table 4 and the results are given in tables 5 to 8.

Group		Usable data pairs	Invalid data
One	CRTVU students using Hounsfield	30	1
Two	UKOU students using Hounsfield	23	0
Three	CRTVUs students using courseware	30	0
Four	UKOU students using courseware	28	0

Table 4 Numbers of cases

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	PRESUM	7.6667	30	2.77406	.50647
	PROSUM	9.5500	30	2.81115	.51324

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	PRESUM - PROSUM	-1.8833	3.15049	.57520	-3.0597	-.7069	-3.274	29	.003

Table 5 Paired-Samples T test for group one,
CRTVU students using Hounsfield

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	PRESUM	8.2609	23	2.62795	.54797
	PROSUM	7.9348	23	2.53298	.52816

		Paired Differences					t	df	Sig. (2-tailed)
			Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	PRESUM - PROSUM	.3261	2.47078	.51519	-.7424	1.3945	.633	22	.533

Table 6 Paired-Samples T test for group two,
UKOU students using Hounsfield

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	PRESUM	7.6667	30	2.90461	.53031
	PROSUM	9.4333	30	2.94412	.53752

		Paired Differences					t	df	Sig. (2-tailed)
			Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Mean	Lower			
Pair 1	PRESUM - PROSUM	-1.7667	3.24498	.59245	-2.9784	-.5550	-2.982	29	.006

Table 7 Paired-Samples T test for group three,
CRTVU students using courseware

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	PRESUM	7.3393	28	3.21758	.60807
	PROSUM	8.0714	28	2.44841	.46271

		Paired Differences					t	df	Sig. (2-tailed)
			Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	PRESUM - PROSUM	-.7321	2.82673	.53420	-1.8282	.3639	-1.371	27	.182

Table 8 Paired-Samples T test for group four,
UKOU students using courseware

The results suggested that there was a statistically significant difference

between PRESUM and PROSUM as $P=0.003<0.05$ for group one and $P=0.006<0.05$ for group three. Therefore for CRTVU students the scores of six questions after taking the tests were improved. However there was not a statistically significant difference between PRESUM and PROSUM as $P=0.533>0.05$ and $P=0.182>0.05$ for groups two and four. This suggests no distinct improvement on the scores of six questions for the UKOU students.

Based on the above discussion, conclusions of the evaluation of the Virtual Laboratory in Materials Science drawn in respect to usability and effectiveness of the software are presented in Chapter 8. Further, some recommendations for the virtual experiment are discussed in Chapter 8 as well.

Chapter 8 Conclusions and recommendations

The Virtual Laboratory in Materials Science was a specialized multimedia program based on non-immersive VR technology to offer a virtual learning or testing environment for distance engineering students. An integrated framework for evaluation including pretest—posttest comparison with both qualitative and quantitative data used in this evaluation informed not only the design of the software but also how it can support the learning process.

8.1 The usability of the Virtual Laboratory in Materials Science

Generally speaking, a simulation of a real experiment environment created by using VR or VEs technology including 3D, image, sound, and video can make a user feel personally on the scene. It may allow the students to feel confident in using the courseware even if some of them are novice users of the computer. This was evident in the results in Chapters 6 and 7. For example, most students (100% of UKOU students and 70% of CRTVUs students) enjoyed using the courseware. And most students (90% of UKOU students and 100% of CRTVUs students) thought the virtual testing laboratory was either easy or very easy to use. In this respect one student said *“Very vivid image that is conducive to learning. The entire process of tensile test is convenient.”* (Subject 47 mentioned in chapter 7)

Among all media used in the courseware, 3D and images were more favoured

and helpful to the students for the usability of the courseware. It was shown in chapter 6, that interaction was important to students in using the courseware to learn and experiment. Video media were well received by a half of the participants who agreed that video was either very helpful or helpful in using the software. But few of them looked carefully at the small video window while carrying out the test. A subject suggested after he finished the test *“It may be better to watch the video before attempting a test.”* In a sense, the usage of video media in a virtual experiment must be considered carefully in the case of movies with small size or low visual resolution due to the limits imposed by early CD-ROM technology. Sounds were not seen as particularly helpful although some participants agreed sounds made the courseware more interesting. Only 5% of UKOU participants and 10% of CRTVU participants thought “sounds are very helpful in using the software for the testing”. This is a much lower percentage than those who thought “3D images, interaction, graphics, and video are very helpful”.

8.2 The effectiveness of the Virtual Laboratory in Materials Science

It was observed that all participants were able to complete the tensile test and the experimental test report using the courseware. This confirmed to a certain extent that the courseware involving virtual technology was a satisfactory way of conducting the experiments especially where the emphasis was on verifying scientific properties and theories without more manual operation.

The findings showed that the use of the Virtual Laboratory in Materials Science could make a contribution to students' understanding of tensile testing. With respect to the courseware, CRTVU participants' scores on questions about tensile testing increased from pretest to posttest. Although UKOU participants' scores of some questions did not increase from pretest to posttest, they conducted the experiment with 100% correctness according to their experimental test reports. And more than half of the students thought their knowledge and skills of the tensile test had improved a lot or quite a lot. The Paired-Samples T Test comparing the means of pretest scores and posttest scores was carried out. The statistical comparisons that were undertaken showed there was a significant difference between the pretest and posttest scores including all questions of the CRTVU students, but not for the UKOU students despite measurable improvements in some questions.

Importantly, this evaluation clearly revealed that VR and VE technology can facilitate and support engineering course learning or even make learning fun.

8.3 Recommendations for virtual experiment

For the tests focused on viewing experimental phenomena like tensile and torsion testing, a virtual experiment may meet basic learning needs in those aspects concerned with practising some simple manipulation and analyzing the various phenomena. But when learning requires steps that need lots of manipulation, the virtual experiment still has some difficulties which need to be resolved. For instance when measuring the sample by using Vernier

callipers, the problem in practice was how to use the calliper on the computer. “Efficacious VE-based training results when knowledge learned through experience in a virtual world improves the performance of the activity in the real world.” (Derek et al, 2003) This suggests the possibility of exploiting VR-based courseware’s advantages to enhance real experiments in engineering education.

In other respects, it seemed that more students liked clear and direct instructions for the process that they could follow easily. The design of the step-by-step control instruction model gave the students little chance to conduct their own investigations, but the main procedures were very clear and students could master the primary information in a short time. However some students preferred to be given more freedom in their manipulation so that they could try every kind of approach or repeat some by themselves. The design idea of individual control instruction described in Chapter 4 was good to stimulate students’ activity in self-study, but students needed to spend more time and it was easy to miss the main process and knowledge when too much information was provided in the courseware. Thus not only prompt instruction was useful but also the help function was really important in computer-based teaching. It might, therefore, be better to provide students with both models of instructions to select from.

8.4 Further Improvements for the evaluation

This evaluation used a pretest-posttest approach outlined by Calder (2001) to explore the efficiency of learning when using VR-based courseware. However, it cannot be assumed that there is a direct relationship between good teaching and the results of student assessment, as learning is a complex activity. Some of the results are more difficult to explain. For example, UKOU participants' scores in some questions did not increase from pretest to posttest but they conducted the experiment with 100% correctness according to their experimental test reports. This implied that discipline questions in the research need to be clearer and contextualized. Further, we can say that good teaching encourages active engagement in the subject matter. So more qualitative data could be collected to display how the learning process using the courseware encourages in the learner a motivation to learn and a desire to understand.

8.5 Summary

This thesis has described an evaluation of specially developed virtual testing courseware, the Virtual Laboratory in Materials Science. The evaluation study used the methodologies that are detailed in Chapter 5 and involved students from the UKOU and CRTVUs who were studying engineering courses. The study indicated that courseware – the Virtual Laboratory in Materials Science – made a contribution to students' general understanding of tensile testing. Indeed there was a measurable increase in students' performance from pretest

to posttest, although the findings did not indicate that the courseware could improve students' concept formation concerning material mechanics properties. The potential of virtual testing courseware in promoting concept teaching clearly needs to be tapped. The research indicated that VR-based courseware was valuable for visualizing materials knowledge by presentation of the experimental phenomena on the computer screen. But as regards experimental skills of manual operation, this was more difficult in this particular non-immersive VR.

To sum up the research, with the trend of distance learning and the growth of VR and VE applications, the virtual laboratory may be an alternative for replacing some real labs in engineering education that form an initial barrier in distance education. The benefits of virtual labs over actual laboratories are found in "their increased portability, cost effectiveness, reduced need for teacher intervention, increased student interest and control, adaptability to various learning styles and learning rates, web ready software and self-testing." (Subramanian et al, 2001) The major finding from the present study of evaluation for VR or VE applications in education showed that the virtual laboratories enhance learning experiences by providing the student with a supplement to the physical lab, but when aiming to improve not only lab skills but also understanding of conceptual knowledge from a virtual experiment, pedagogic design including instructions and tutorials may be more important than the technology design involving visual presentation of

the virtual laboratory. This supports the finding reported by others that “VR technology is capable of affording constructive learning.” (Chen et al, 2005).

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Appendix 1 Evaluation Questionnaires control groups

Evaluation Questionnaire for control group (English)

This questionnaire is part of an evaluation that is being carried out in Britain and China. It is being used to evaluate a computer program, called “Virtual Testing Laboratory”. To do this some students will be working with this software and others with a testing machine in a laboratory. The outcome of the evaluation should help to find ways of improving the software to make it more effective for students.

I would be very grateful if you could answer the following questions by filling in information or by ticking boxes where appropriate. The information you provide will be strictly confidential and used for no purpose other than the evaluation of the software. Thank you in advance for your contribution to this evaluation.

This evaluation could take you about two hours. In this session you will answer some questions first before you make the tests. Then you will use testing machine to carry out a tensile test. A researcher will be there with you to help you out if you get stuck. Please talk aloud as you do the tests and tell the researcher what you do not understand. When you finish the tests, a questionnaire will be used to ask you some questions about the tests.

Thank you very much.

Please note: None of the information collected in this experiment will be linked to your OU personal record.

Nationality:

Mother language:

Gender:

Age:

Please tick all those you think appropriate.

1. What educational background do you have?

- A. No formal qualifications
- B. Some qualifications (e.g. CSE, O levels/GCSE, A levels, OND etc)
- C. Higher qualification (e.g. HND, HNC, teaching certificate, degree etc)
- D. Some OU courses in an engineering subject

2. Which computer operating systems have you used?

- A. Windows
- B. Dos
- C. Mac OS
- D. Unix
- E. Others (Please list)

3. Which types of computer packages have you used?
 - A. Word-processing
 - B. Spreadsheets
 - C. Databases
 - D. Graphics/drafting software
 - E. Multimedia tutorials or simulations

4. How often would you say you use a computer?
 - A. Every day
 - B. Every 2-3 days
 - C. Once a week
 - D. Once a month
 - E. Less than once a month
 - F. Never

5. How skilled do you think you are at using a computer?
 - A. Expert
 - B. Advanced
 - C. Competent
 - D. Novice
 - E. Never used one

Part one (Pretest)

1. Below are illustrations of three different tests. Which one of these illustrations shows a tensile test?



Figure a
Specimen fixed between grips, one fixed and one can be moved. When grip moves apart, the specimen is pulled until it breaks.

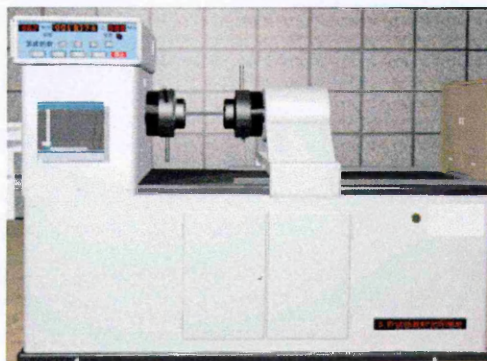


Figure b
Specimen fixed between grips, Left-grip rotates either clock-wise or anti-clock wise.

- A. Figure a
- B. Figure b
- C. Figure c
- D. Do not know

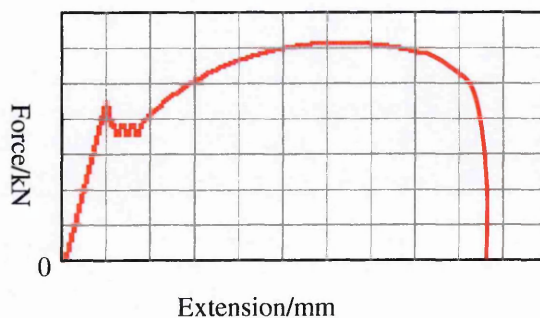


Figure c
Specimen is laid horizontally on the supports, and head applies force to centre of specimen.

2. Using which instrument could you measure the dimensions of the specimen accurately for a tensile test?

- A. A ruler
- B. Vernier calipers
- C. Micrometer
- D. Tape measure
- E. Do not know

3. What does the graph below show?



- A. It might be a force-extension curve for steel.
- B. It might be a force-extension curve for glass.
- C. It might be a force-extension curve for polypropylene.
- D. Do not know

4. How could you get the graph showed above?
- A. It can be plotted by a recorder automatically or manually from tensile test data.
 - B. It can be plotted by calculation from Hooke’s law.
 - C. It could be plotted from elastic and plastic materials properties.
 - D. Do not know.
5. Suppose you are carrying out a tensile test for a low carbon steel specimen. Do you know what would happen to the specimen when it is extended beyond the maximum load in a force-extension graph?
- A. The specimen will be broken
 - B. The specimen will be extended but if unloaded the deformation will disappear
 - C. The specimen will show localized thinning
6. What is the sequence of main steps in a tensile test? (Match an appropriate sentence to each step)

Step one	Measure the specimen’s broken sizes
Step two	Record the data in test report
Step three	Set test conditions
Step four	Measure the specimen’s original sizes
Step five	Load the specimen
Step six	Fix the specimen in the test machine

Task one

Tensile test
Instruction for tensile test by Hounsfield Tensometer

Objectives

- Through a tensile test for mild steel specimen, obtain the following data:
- 1. Original dimensions of specimen (including gauge length, width, and thickness).
 - 2. The values of force and extension corresponding to the load at yield point, and the maximum load
 - 3. The dimensions of specimen after fracture

4. The yield stress
5. The ultimate tensile strength (UTS)
6. % elongation
7. % Reduction in area

Procedure

- Step 1 Accurately measuring the original specimen dimensions (gauge length, width, and thickness).
- Step 2 Locate the specimen in the grips (use vice and spanner)
- Step 3 Fix the specimen to the machine (use coarse travel to position cross head)
- Step 4 Put the guard over specimen
- Step 5 Switch on chart recorder power
- Step 6 Put the pen in
- Step 7 Set chart speed to "3"
- Step 8 Pull the pen down
- Step 9 Switch "chart" to "forward"
- Step 10 Zero the digital readout using pressing "reset" and set displaying the max load using pressing "max/min" button
- Step 11 Turn the motor switch to "forward"
- Step 12 Wait and watch for yield point and necking
- Step 13 Turn the motor switch to "off" to stop cross head when the specimen breaks
- Step 14 Move chart button to "zero"
- Step 15 Lift the pen and take the pen out
- Step 16 Move the "Pos" button to forward the recording paper and tear it off
- Step 17 Press the "max/min" button on digital readout to get the max load
- Step 18 Measure the specimen broken dimensions (gauge length, width, and thickness).
- Step 19 Fill in the experiment Report

Part two (Posttest)

Section A

1. Below are illustrations of three different tests. Which one of these illustrations shows a tensile test?

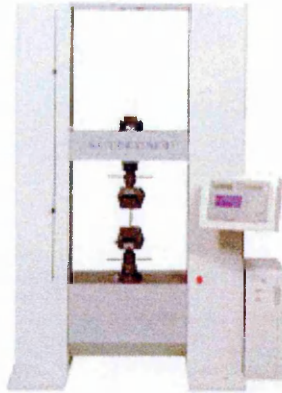


Figure a
Specimen fixed between grips, one fixed and one can be moved. When grip moves apart, the specimen is pulled until it breaks.



Figure b
Specimen fixed between grips, Left-grip rotates either clock-wise or anti-clock wise.

- A. Figure a
- B. Figure b
- C. Figure c
- D. Do not know

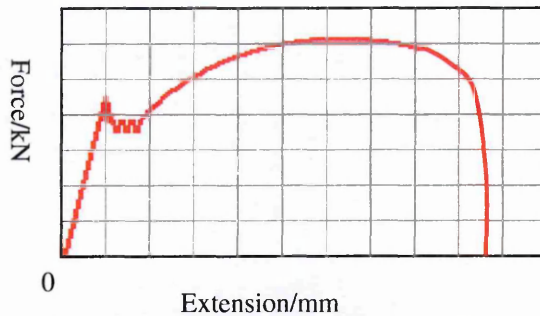


Figure c
Specimen is laid horizontally on the supports, and head applies force to centre of specimen.

2. Using which instrument could you measure the dimensions of the specimen accurately for a tensile test?

- A. A ruler
- B. Vernier calipers
- C. Micrometer
- D. Tape measure
- E. Do not know

3. What does the graph below show?



- A. It might be a force-extension curve for steel.
 - B. It might be a force-extension curve for glass.
 - C. It might be a force-extension curve for polypropylene.
 - D. Do not know
4. How could you get the graph showed above?
- A. It can be plotted by a recorder automatically or manually from tensile test data.
 - B. It can be plotted by calculation from Hooke's law.
 - C. It could be plotted from elastic and plastic materials properties.
 - D. Do not know.
5. Suppose you are carrying out a tensile test for a low carbon steel specimen. Do you know what would happen to the specimen when it is extended beyond the maximum in a force-extension graph?
- A. The specimen will be broken
 - B. The specimen will be extended but if unloaded the deformation will disappear
 - C. The specimen will be local thinning
6. What is the sequence of main steps in a tensile test? (Match an appropriate sentence to each step)

Step one	Measure the specimen's broken sizes
Step two	Record the data in test report
Step three	Set test conditions
Step four	Measure the specimen's original sizes
Step five	Load the specimen
Step six	Fix the specimen in the test machine

Section B

1. Did you like using Hounsfield Tensometer to do tensile test?

- A. Liked it very much
- B. Liked it
- C. Liked it little
- D. Did not like

2. Was the tensile test?

- A. Very interesting
- B. Interesting
- C. Boring
- D. Very boring

3. Was Hounsfield Tensometer easy to use?

- A. Very easy
- B. Easy
- C. Quite difficult
- D. Very difficult

4. Which sections of the tensile test did you find difficult or unclear? What are your suggestions for improvements?

Difficult/unclear sections	Suggestions for improvements
Measurement for specimen's sizes	
Controlling the machine	
Fixing the specimen to the machine	
Getting test data from the curve	
Setting recorder	
The overall procedure of the tensile test	
Other(please state)	

5. If you got 'stuck' at any point (due to difficulty or unclear instructions), how did you get yourself 'unstuck'? (Please give details)

6. Do you think your knowledge and skills of tensile test have improved by using Hounsfield Tensometer?

- A. A lot
- B. Quite a lot
- C. Slightly
- D. Not at all

Evaluation Questionnaire for control group (Chinese)

评估问卷 (对于实验机使用者)

这份问卷是在英国和中国进行的《虚拟力学实验室软件》评估的一部分。此项评估在两组学生中进行，一组学生使用《虚拟力学实验室软件》完成指定的力学实验而另一组则使用材料实验机完成同样的力学实验。评估结果将有助于改进该软件使之更有利于学生学习。

非常感谢你回答以下的问题，请填写有关的信息或在你认为合适的框内打勾。你所提供的信息将被严格保密并不被用于除本评估以外的其他目的。

对于你对本评估所做的贡献，在此表示衷心的感谢。

本评估将花费你两个小时左右的时间。首先，请你回答第一部分的问题；然后，请你使用实验机完成拉伸实验和扭转实验，如果你遇到困难，有关人员将会给你帮助，请说出你不理解的地方；完成实验后，请回答有关实验内容的有关问题。

再次感谢你。

请注意：本次评估所收集的任何资料不计入你在电大的学习成绩。

国籍:

母语:

性别:

年龄:

请在所有你认为合适的选项上打勾。

1.你具有怎样的教育背景?

A. 没有正式的证书

- B. 初级证书（例如，初中毕业，高中毕业，职业高中，中专等）
- C. 高级证书（例如，教师证书，工程师证书，学位证书等
- D. 电大工程专业的课程

2. 你用过哪个计算机操作系统？

- A. Windows
- B. Dos
- C. Mac OS
- D. Unix
- E. 其它（请列出来）

3. 你用过哪些应用软件？

- A. 文字处理软件
- B. Spreadsheets
- C. 数据库
- D. 图形/画图软件
- E. 多媒体教学软件/仿真软件

4.你多长时间用一次计算机？

- A. 每天
- B. 隔 2-3 天
- C. 一星期一次
- D. 一个月一次

E. 每月少于一次

F. 从未用过

5. 你用计算机有多熟练?

A. 专家级

B. 老手

C. 会用

D. 新手

E. 从未用过

第一部分 (Pre-test)

1. 下面是三个不同实验的图示, 其中哪个是拉伸实验?

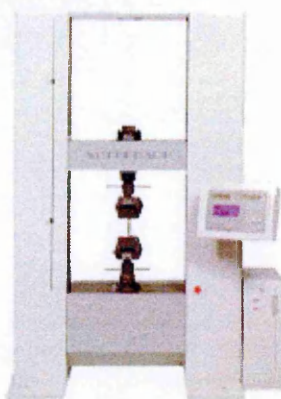


图 a
试样固定在夹头之间，
一端固定，另一端可移动，
使得试样被拉直至拉断



图 b
试样固定在夹头之间，
左夹头可顺时针或逆时针转动

- A. 图 a
- B. 图 b
- C. 图 c
- D. 不知道

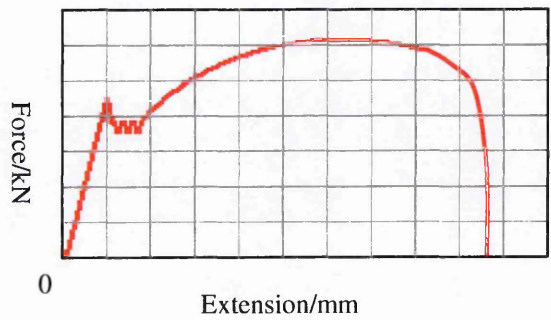


图 c
试样水平放置在支承上，施力头施加载荷于试样中部

2. 在拉伸实验中，使用哪种设备可以精确测量试样直径？

- A. 尺子
- B. 游标卡尺
- C. Micrometer
- D. 卷尺
- E. 不知道

3. 以下图形是什么？



- A. 可能是钢材的力与变形曲线.
- B. 可能是玻璃的力与变形曲线.
- C. 可能是聚丙烯的力与变形曲线

D. 不知道

4. 如何获得上图所示的曲线?

- A. 可由记录仪自动描绘或根据拉伸数据手工描绘
- B. 通过胡克定律计算而得
- C. 根据材料的弹性和塑性性质描绘而得
- D. 不知道

5. 假设你正在进行低碳钢拉伸实验，你是否知道当载荷达到力与变形曲线的载荷最大值时，试样将会发生什么变化?

- A. 试样将会断裂
- B. 试样将被拉伸变形但如果卸载变形将消失
- C. 试样将局部颈缩

6. 拉伸实验的主要步骤是什么? (用线连接相应的实验步骤)

第一步:	测量试样断后尺寸
第二步:	将实验数据填写到实验报告
第三步:	设置实验条件
第四步:	测量试样原始尺寸
第五步:	加载
第六步:	安装试样

任务一

拉伸实验

在 HOUNSFIELD 上进行拉伸实验的说明。

目的：

通过低碳钢拉伸实验，得到以下数据：

1. 试样原始尺寸 (包括标距，横截面宽度和厚度).
2. 屈服载荷和最大载荷
3. 试样断后尺寸(包括断后标距长度，断口横截面宽度和厚度)
4. 屈服应力
5. 强度极限
6. 延伸率
7. 截面收缩率

步骤：

第一步 精确测量试样原始尺寸（标距，横截面宽度和厚度）

第二步 把试样安装在夹头中（用摇把移动十字头从而定位）

第三步 把水银柱回零，指针和记录臂均对零

第四步 转动十字头微动摇柄，施加少量载荷使试样装夹好

第五步 把绘图纸装到磁鼓上

第六步 向下压绘图针头在绘图纸上做记号

第七步 转动摇把拉伸试样，按照水银柱的高度在绘图纸上作记号，不要转动摇把太快，以

免加载过快使得错过屈服点。继续加载直至试样断裂

第八步 试样断裂后，取下试样，测量断后尺寸

第九步 填写实验报告

第二部分 (Post-tests)

(A)

1. 下面是三个不同实验的图示，其中哪个是拉伸实验？

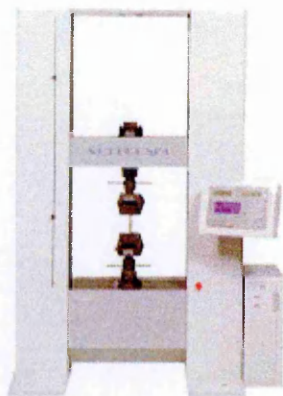


图 a
试样固定在夹头之间，一端固定，另一端可移动，使得试样被拉直至拉断

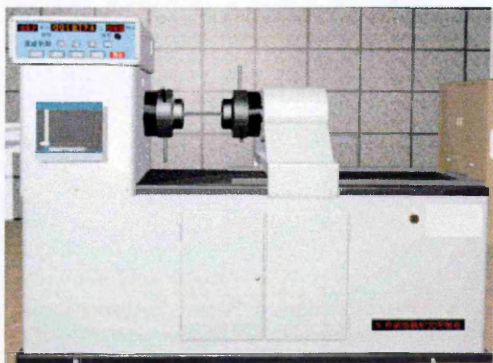


图 b
试样固定在夹头之间，左夹头可顺时针或逆时针转动



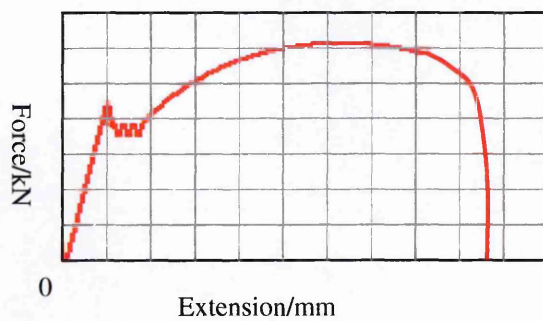
图 c
试样水平放置在支承上，施力头施加载荷于试样中部

- A. 图 a
- B. 图 b
- C. 图 c
- D. 不知道

2. 在拉伸实验中，使用哪种设备可以精确测量试样直径？

- A. 尺子
- B. 游标卡尺
- C. Micrometer
- D. 卷尺
- E. 不知道

3. 以下图形是什么？



- A. 可能是钢材的力与变形曲线.
- B. 可能是玻璃的力与变形曲线.
- C. 可能是聚丙烯的力与变形曲线
- D. 不知道

4. 如何获得上图所示的曲线？

- A. 可由记录仪自动描绘或根据拉伸数据手工描绘
- B. 通过胡克定律计算而得
- C. 根据材料的弹性和塑性性质描绘而得
- D. 不知道

5. 假设你正在进行低碳钢拉伸实验，你是否知道当载荷达到力与变形曲线的载荷最大值时，
试样将会发生什么变化？

- A. 试样将会断裂
- B. 试样将被拉伸变形但如果卸载变形将消失
- C. 试样将局部颈缩

6. 拉伸实验的主要步骤是什么? (用线连接相应的实验步骤)

第一步:	测量试样断后尺寸
第二步:	将实验数据填写到实验报告
第三步:	设置实验条件
第四步:	测量试样原始尺寸
第五步:	加载
第六步:	安装试样

(B)

1.你是否喜欢使用 HOUNSFIELD 做拉伸实验?

- A. 非常喜欢
- B. 喜欢
- C. 不太喜欢
- D. 不喜欢

2. 你如何认为拉伸实验?

- A. 非常有趣
- B. 有趣

- C. 无聊
- D. 非常无聊

3. HOUNSFIELD 是否便于使用?

- A. 非常容易
- B. 容易
- C. 有点难
- D. 非常难

4. 你认为拉伸实验中哪一部分困难或不明白? 有何改进建议?

困难或不明白部分	改进建议
测量试样尺寸	
控制实验机	
装夹试样	
从实验曲线上获得实验数据	
设置 X-Y 记录仪	
拉伸实验的全过程	
其它(请说明)	

5.如果你陷入困境（由于困难或指导不清楚），你如何摆脱困境？（请详细说明）

6.你是否认为通过使用 HOUNSFIELD，你在拉伸实验方面的知识和技能有所提高？

- A. 很大提高
- B. 提高
- C. 不太提高
- D. 没有提高

Appendix 2 Evaluation Questionnaires for treatment groups

Evaluation Questionnaire for treatment group (English)

This questionnaire is part of an evaluation that is being carried out in Britain and China. It is being used to evaluate a computer program, called “Virtual Testing Laboratory”. To do this some students will be working with this software and others with a testing machine in a laboratory. The outcome of the evaluation should help to find ways of improving the software to make it more effective for students.

I would be very grateful if you could answer the following questions by filling in information or by ticking boxes where appropriate. The information you provide will be strictly confidential and used for no purpose other than the evaluation of the software. Thank you in advance for your contribution to this evaluation.

This evaluation could take you about two hours. In this session you will answer some questions first before you make the tests. Then you will use the software to carry out a tensile test and a torsion test. A researcher will be there with you to help you out if you get stuck. Please talk aloud as you do the tests and tell the researcher what you do not understand or what things you think are not well designed about the software. When you finish the tests, a questionnaire will be used to ask you some questions about the tests and the use of the software.

Thank you very much.

Please note: None of the information collected in this experiment will be linked to your OU personal record.

Nationality:

Mother language:

Gender:

Age:

Please tick all those you think appropriate.

1. What educational background do you have?

- A. No formal qualifications
- B. Some qualifications (e.g. CSE, O levels/GCSE, A levels, OND etc)
- C. Higher qualification (e.g. HND, HNC, teaching certificate, degree etc)
- D. Some OU courses in an engineering subject

2. Which computer operating systems have you used?

- A. Windows
- B. Dos
- C. Mac OS
- D. Unix
- E. Others (Please list)

3. Which types of computer packages have you used?
- A. Word-processing
 - B. Spreadsheets
 - C. Databases
 - D. Graphics/drafting software
 - E. Multimedia tutorials or simulations
4. How often would you say you use a computer?
- A. Every day
 - B. Every 2-3 days
 - C. Once a week
 - D. Once a month
 - E. Less than once a month
 - F. Never
5. How skilled do you think you are at using a computer?
- A. Expert
 - B. Advanced
 - C. Competent
 - D. Novice
 - E. Never used one

Part one (Pretest)

1. Below are illustrations of three different tests. Which one of these illustrations shows a tensile test?

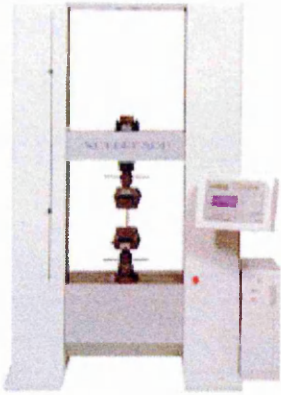


Figure a
Specimen fixed between grips, one fixed and one can be moved. When grip moves apart, the specimen is pulled until it breaks.



Figure b
Specimen fixed between grips, Left-grip rotates either clock-wise or anti-clock wise.

- A Figure a
- B Figure b
- C Figure c
- D Do not know

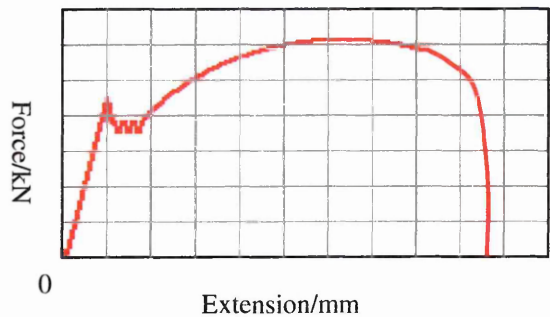


Figure c
Specimen is laid horizontally on the supports, and head applies force to centre of specimen.

2. Using which instrument could you measure the dimensions of the specimen accurately for a tensile test?

- A. A ruler
- B. Vernier calipers
- C. Micrometer
- D. Tape measure
- E. Do not know

3. What does the graph below show?



- A. It might be a force-extension curve for steel.
 - B. It might be a force-extension curve for glass.
 - C. It might be a force-extension curve for polypropylene.
 - D. Do not know
4. How could you get the graph showed above?
- A. It can be plotted by a recorder automatically or manually from tensile test data.
 - B. It can be plotted by calculation from Hooke’s law.
 - C. It could be plotted from elastic and plastic materials properties.
 - D. Do not know.
5. Suppose you are carrying out a tensile test for a low carbon steel specimen. Do you know what would happen to the specimen when it is extended beyond the maximum load in a force-extension graph?
- A. The specimen will be broken
 - B. The specimen will be extended but if unloaded the deformation will disappear
 - C. The specimen will be local thinning
6. What is the sequence of main steps in a tensile test? (Match an appropriate sentence to each step)

Step one	Measure the specimen’s broken sizes
Step two	Record the data in test report
Step three	Set test conditions
Step four	Measure the specimen’s original sizes
Step five	Load the specimen
Step six	Fix the specimen in the test machine

Task one

Tensile test

Instruction for tensile test by virtual testing machine

Objectives

Through a tensile test for low carbon steel specimen, obtain the following data:

1. Original dimensions of specimen (including gauge length, diameter of cross-section of specimen).
2. The values of force and extension corresponding to the load at yield point, and the maximum load
3. The dimensions of specimen after fracture (including gauge length, diameter of the cross-section near the broken point)
4. Yield stress
5. UTS
6. % Elongation
7. % Reduction in area

Procedure

Step 1 Click on “Tensile test” icon

Step 2 Click “specimen” icon and then select the upper specimen (low carbon steel) for testing. Drag the specimen onto the measurement area.

Step 3 Now measure the specimen dimensions by means of the calipers. Take two measurements (in mutual vertical directions) of one cross-sectional area (e.g. Section I) and type your results into the data block.

Step 4 Click “OK” button or drag the specimen to testing desk, then click on close button.

Step 5 Click the power button (located on tensile frame) to turn the “power” on.

Step 6 Drag the specimen to the jaws of the testing machine.

Step 7 Click the “control panel” icon (this will enlarge the panel) then click “setting test condition” icon (this will activate automatic set-up of testing condition). When set, click on close button to minimize control panel.

Step 8 Click the handle of the upper grip to open the taper jaws. Repeat for the lower grip.

Step 9 Drag the specimen to the upper grip then click on the handle to close the taper jaws onto the specimen.

Step 10 Click the “down” button to move specimen into the lower grip.

Step 11 Click the lower handle to close the taper jaws.

Step 12 Click on the “X-Y record” icon to enlarge the recorder.

Step 13 Click three on/off switches to register an “on” position.

Step 14 Go to main panel and click the “up” switch to activate the test.
Step 15 Follow the instructions that will appear on screen at the end of the test.
Step 16 Click on the “continue” button to view the fracture surface.
Step 17 Click “continue” to return to test system.
Step 18 Click three “close” buttons to exit from the three windows on screen.
Step 19 Click specimen box again. This will enable you to measure the fractured specimen. Do not forget to record your measurements in the data box.
Step 20 Click on the “close” button.
Step 21 Click on the “report” icon to obtain your experimental data report and fill in the experiment report. Check your testing results.

Task two

Torsion test

Instruction for torsion test by virtual testing machine.

Objectives

Through torsion test for low carbon steel specimen, obtain the data:

1. The values of the moment at yield point
2. The maximum moment

Procedure

Step 1 Click “Torsion Test” icon.
Step 2 Click “specimen” icon, choose the specimen to test and take the appropriate measurements.
Step 3 Click “exit” to close the windows and return to main “window”.
Step 4 Click “power” button then the power is turned on.
Step 5 Drag the specimen to testing machine.
Step 6 Follow the instructions that appear on the screen.

Part two (Posttest)

Section A

1. Below are illustrations of three different tests. Which one of these illustrations shows a tensile test?

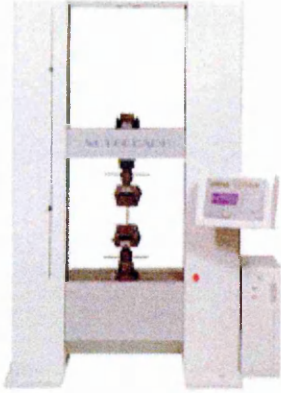


Figure a
Specimen fixed between grips, one fixed and one can be moved. When grip moves apart, the specimen is pulled until it breaks.



Figure b
Specimen fixed between grips, left-grip rotates either clock-wise or anti-clock wise.

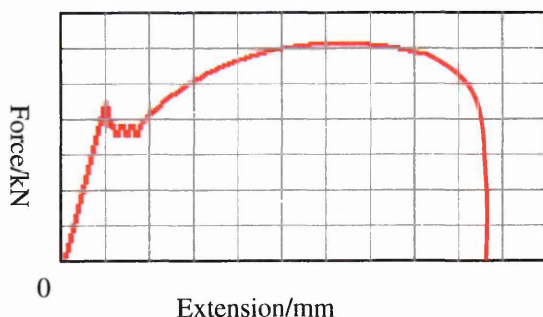
- A. Figure a
- B. Figure b
- C. Figure c
- D. Do not know



Figure c
Specimen is laid horizontally on the supports, and head applies force to centre of specimen.

2. Using which instrument could you measure the diameter of the specimen accurately for a tensile test?
 - A. A ruler
 - B. Vernier calipers
 - C. Micrometer
 - D. Tape measure
 - E. Do not know

3. What is the graph below?



- A. It might be a force-extension curve for steel.
 - B. It might be a force-extension curve for glass.
 - C. It might be a force-extension curve for polypropylene.
 - D. Do not know
4. How could you get the graph showed above?
- A. It can be plotted by an X-Y recorder automatically or from the data recorded by a testing machine manually.
 - B. It can be plotted by a recorder automatically or manually from tensile test data.
 - C. It can be plotted by calculation from Hooke's law.
 - D. It could be plotted from elastic and plastic materials properties.
 - E. Do not know.
5. Suppose you are carrying out a tensile test for a low carbon steel specimen. Do you know what would happen to the specimen when it is extended beyond the maximum in a force-extension graph?
- A. The specimen will be broken
 - B. The specimen will be extended but if unloaded the deformation will disappear
 - C. The specimen will be local thinning
6. What is the sequence of steps in a tensile test? (Match an appropriate sentence to each step)

Step one	Measure the specimen's broken sizes
Step two	Record the data in test report
Step three	Set test conditions
Step four	Measure the specimen's original sizes
Step five	Load the specimen

Section B

1. Did you like using the virtual testing laboratory?
- A. Liked it very much
 - B. Liked it
 - C. Liked it little
 - D. Did not like

2. Was the virtual testing laboratory easy to use?
- A. Very easy
 - B. Easy
 - C. Quite difficult
 - D. Very difficult

3. To enable us to gauge your thoughts about the tensile test and the torsion test please tick to indicate how strongly you agree with the following statements.

Statements	Agree	Slightly agree	Slightly disagree	Disagree
Instructions (step by step prompts and Help facility) in torsion test is better than instruction in tensile test (just Help facility)				
The sounds used during the tensile test make it more interesting than the torsion test				
Other comments (please state)				

4. Which aspects did you find most helpful in your using the software for testing?

	Very helpful	Helpful	Helpful a little	No helpful
3D images(e.g. the testing machine, specimens and calipers, etc)				
Videos				
Graphics(2D images)				
Sounds				

Interaction				
Others(please comment)				

5. Which sections of the software did you find difficult or unclear in the program? What are your suggestions for improvements?

Difficult/unclear sections	Suggestions for improvements
Measurement for specimen's sizes	
Controlling the machine	
Fixing the specimen to the machine	
Getting test data from the curve	
Setting X-Y recorder	
The overall procedure of the tensile test	
The procedure of the torsion test	
Other(please state)	

6. If you got 'stuck' at any point (due to difficulty or unclear instructions), how did you get yourself 'unstuck'? (Please give details)

7. Do you think your knowledge and skills of tensile and torsion tests have improved by using the virtual testing laboratory?

- A. A lot
- B. Quite a lot
- C. Slightly
- D. Not at all

8. Was the tensile test?

- A. Very interesting
- B. Interesting
- C. Boring
- D. Very boring

Evaluation Questionnaire for treatment group (Chinese)

评估问卷 (对于软件使用者)

这份问卷是在英国和中国进行的《虚拟力学实验室软件》评估的一部分。此项评估在两组学生中进行，一组学生使用《虚拟力学实验室软件》完成指定的力学实验而另一组则使用材料实验机完成同样的力学实验。评估结果将有助于改进该软件使之更有利于学生学习。

非常感谢你回答以下的问题，请填写有关的信息或在你认为合适的框内打勾。你所提供的信息将被严格保密并不被用于除本评估以外的其他目的。

对于你对本评估所做的贡献，在此表示衷心的感谢。

本评估将花费你两个小时左右的时间。首先，请你回答第一部分的问题；然后，请你使用实验机完成拉伸实验和扭转实验，如果你遇到困难，有关人员将会给你帮助，请说出你不理解的地方；完成实验后，请回答有关实验内容的有关问题。

再次感谢你。

请注意：本次评估所收集的任何资料不计入你在电大的学习成绩。

国籍:

母语:

性别:

年龄:

请在所有你认为合适的选项上打勾。

1. 你具有怎样的教育背景?

A. 没有正式的证书

- B. 初级证书（例如，初中毕业，高中毕业，职业高中，中专等）
- C. 高级证书（例如，教师证书，工程师证书，学位证书等
- D. 电大工程专业的课程

2. 你用过哪个计算机操作系统?

- A. Windows
- B. Dos
- C. Mac OS
- D. Unix
- E. 其它 (请列出来)

3. 你用过哪些应用软件?

- A. 文字处理软件
- B. Spreadsheets
- C. 数据库
- D. 图形/画图软件
- E. 多媒体教学软件/仿真软件

4.你多长时间用一次计算机?

- A. 每天
- B. 隔 2-3 天
- C. 一星期一次
- D. 一个月一次

E. 每月少于一次

F. 从未用过

5. 你用计算机有多熟练?

A. 专家级

B. 老手

C. 会用

D. 新手

E. 从未用过

第一部分 (Pre-test)

1. 下面是三个不同实验的图示，其中哪个是拉伸实验?



图 a
试样固定在夹头之间，
一端固定，另一端可移动，
使得试样被拉直至拉断



图 b
试样固定在夹头之间，
左夹头可顺时针或逆时针转动

A. 图 a

B. 图 b

C. 图 c

D. 不知道



图 c

试样水平放置在支承上，施力头施加载荷于试样中部

2. 在拉伸实验中，使用哪种设备可以精确测量试样直径？

A. 尺子

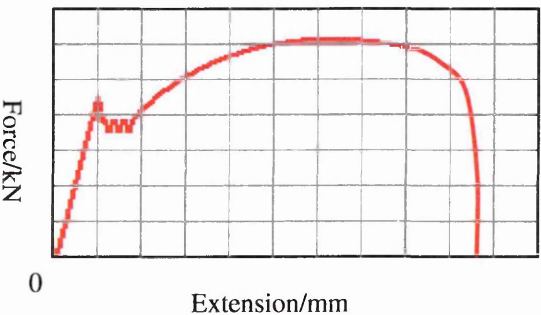
B. 游标卡尺

C. Micrometer

D. 卷尺

E. 不知道

3. 以下图形是什么？



A. 可能是钢材的力与变形曲线.

B. 可能是玻璃的力与变形曲线.

C. 可能是聚丙烯的力与变形曲线

D. 不知道

4. 如何获得上图所示的曲线?
- A. 可由记录仪自动描绘或根据拉伸数据手工描绘
 - B. 通过胡克定律计算而得
 - C. 根据材料的弹性和塑性性质描绘而得
 - D. 不知道
5. 假设你正在进行低碳钢拉伸实验, 你是否知道当载荷达到力与变形曲线的载荷最大值时, 试样将会发生什么变化?
- A. 试样将会断裂
 - B. 试样将被拉伸变形但如果卸载变形将消失
 - C. 试样将局部颈缩
6. 拉伸实验的主要步骤是什么? (用线连接相应的实验步骤)

第一步:	测量试样断后尺寸
第二步:	将实验数据填写到实验报告
第三步:	设置实验条件
第四步:	测量试样原始尺寸
第五步:	加载
第六步:	安装试样

任务一

拉伸实验

虚拟拉伸实验说明

目的

通过低碳钢拉伸实验，得到以下数据：

1. 试样原始尺寸 (包括标距，横截面直径).
2. 屈服载荷和最大载荷
3. 试样断后尺寸(包括断后标距长度，断口横截面直径)
4. 屈服应力
5. 强度极限
6. 延伸率
7. 截面收缩率

步骤

第一步 点击“拉伸实验”图标。

第二步 点击“试样”图标选择低碳钢试样进行实验。拽拉试样至测量区。

第三步 用游标卡尺测量试样尺寸，在某个横截面（例如截面一）互相垂直方向各测一次直径，将结果输入数据窗口。

第四步 点击“OK”按钮或拽拉试样至实验台然后点击“Close”按钮。

第五步 点击“电源”按钮（在拉伸实验机机架上）打开电源。

第六步 拽拉试样至实验机。

第七步 点击“控制面板”放大控制面板，点击“实验设置”系统将自动设置实验条件。设置完成后点击“CLOSE”缩小控制面板。

第八步 点击上夹头的手柄旋松夹头，对下夹头重复此动作。

第九步 拽拉试样至上夹头然后点击手柄旋紧夹头。

第十步 点击“down”按钮使试样向下运动插入下夹头。

第十一步 点击下夹头手柄旋紧夹头。

第十二步 点击“X-Y 记录仪”图标放大记录仪。

第十三步 点击 on/off 开关使三个开关均处于“on”位置。

第十四步 点击控制面板上的“up”按钮开始实验。

第十五步 按照屏幕出现的提示进行实验。

第十六步 点击“继续”按钮观察断口。

第十七步 点击“继续”按钮退出实验。

第十八步 点击“close”按钮关闭三个小窗口。

第十九步 再次点击试样箱图标，测量试样断后尺寸。记得在数据窗口记录测量结果。

第二十步 点击“close”按钮。

第二十一部 点击“实验报告”图标，填写实验报告。检查实验结果。

第二部分 (Post-tests)

(A)

1. 下面是三个不同实验的图示，其中哪个是拉伸实验？



图 a
试样固定在夹头之间，
一端固定，另一端可移动，
使得试样被拉直至拉断

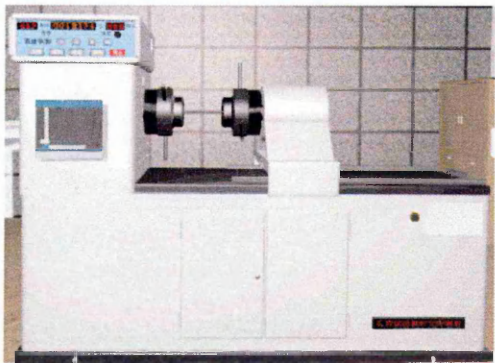


图 b
试样固定在夹头之间，
左夹头可顺时针或逆时针转动

- A. 图 a
- B. 图 b
- C. 图 c
- D. 不知道

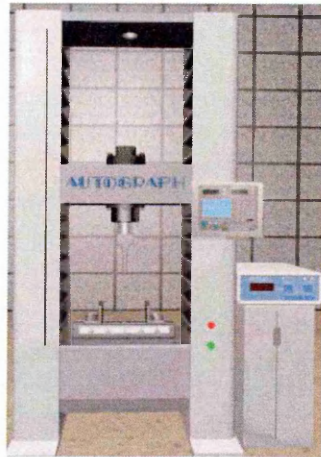
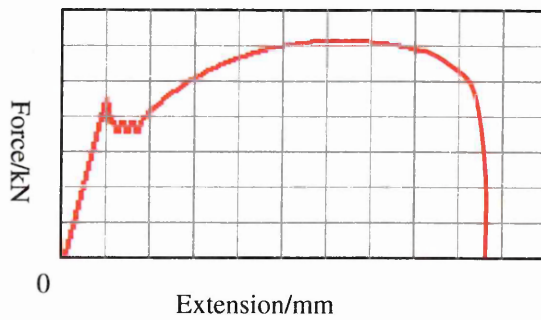


图 c
试样水平放置在支承上，施力头施加载荷于试样中部

2. 在拉伸实验中，使用哪种设备可以精确测量试样直径？

- A. 尺子
- B. 游标卡尺
- C. Micrometer
- D. 卷尺
- E. 不知道

3. 以下图形是什么？



- A. 可能是钢材的力与变形曲线.
- B. 可能是玻璃的力与变形曲线.

- C. 可能是聚丙烯的力与变形曲线
- D. 不知道
4. 如何获得上图所示的曲线?
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- B. 通过胡克定律计算而得
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5. 假设你正在进行低碳钢拉伸实验, 你是否知道当载荷达到力与变形曲线的载荷最大值时, 试样将会发生什么变化?
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第四步:	测量试样原始尺寸
第五步:	加载
第六步:	安装试样

(B)

1. 你是否喜欢使用虚拟实验室软件?

- A. 非常喜欢
- B. 喜欢
- C. 不太喜欢
- D. 不喜欢

2.虚拟实验室软件是否便于使用?

- A. 非常容易
- B. 容易
- C. 有点难
- D. 非常难

3.为使我们准确了解你对拉伸实验和扭转实验的看法，请在合适的框内打勾，表明你对下面结论的同意程度。

结论	同意	基本同意	基本不同意	不同意
扭转实验中的指导(一步一步给提示以及帮助功能) 好于拉伸实验中的指导（只有帮助功能）				
拉伸实验中应用了声音使拉伸实验比扭转实验更有趣				
其它评论 (请说明)				

4.当你使用软件做实验时，哪些因素对你更有帮助？

	非常有帮助	有帮助	基本没帮助	没帮助
三维形象(例如，实验机,试样和卡尺等)				
录象				
图形(二维形象)				
声音				
交互				
其它(请说明)				

5.你认为软件中哪一部分使用困难或不明白？有何改进建议？

困难或不明白部分	改进建议
测量试样尺寸	
控制实验机	
装夹试样	
从实验曲线上获得实验数据	
设置 X-Y 记录仪	
拉伸实验的全过程	
扭转实验过程	
其它(请说明)	

6.如果你陷入困境（由于困难或指导不清楚），你如何摆脱困境？（请详细说明）

7.你是否认为通过使用虚拟实验室软件，你在拉伸和扭转实验方面的知识和技能有所提高？

A. 很大提高

B. 提高

C. 不太提高

D. 没有提高

8. 你如何认为拉伸实验？

A. 非常有趣

B. 有趣

C. 无聊

D. 非常无聊

Appendix 3 Experiment Report

Name:
Date:
Time:
Material: Low carbon steel

Step one

Please measure the dimensions of the specimen and fill in the form below.

Specimen Size			
Before test	Gauge length /mm	Diameter of cross section 1 within gauge length /mm	Diameter of cross section 1 within gauge length /mm
After test	Gauge length /mm	Diameter of cross section 1 near the breaking point /mm	Diameter of cross section 1 near breaking point /mm

Step two

Please go to the reckoner in computer and calculate tensile property data.

Step three

Please get the data from the reckoner and fill in the form below.

Data from the recorder	Load at yield point/kN	
	Maximum load/kN	
Properties	Yield stress/MPa	
	UTS/MPa	
	% Elongation	
	% Reduction in Area	

Appendix 4 Tensile property data reckoner

Tensile property data reckoner

Enter data:	Cross head speed/mm min-1	3.5
	Chat speed/ mm min-1	30
	Original diameter of cross section 1/mm	9.82
	Original diameter of cross section 1/mm	10.06
	Original gauge length	50
	Fracture diameter of cross section 1 area/mm	8.42
	Fracture diameter of cross section 1 area/mm	8.5
	Fracture gauge length	67.4
	Load at the yield point/kN	24.02
	Maximum load/kN	30.85

Read off:	Original cross section area/ mm^2	77.60016598
	Fracture cross section area/ mm^2	56.21220319
	Yield stress/MPa	309.5354204
	UTS/MPa	397.5506961
	%Elongation	34.8
	%Reduction in area	27.56174876

Appendix 5 The sample of the program

Programme on how to achieve imitating tensile testing procedure with a picture of the result shown as figure 4-6.

```
if ~Checked@"电源" then
```

```
    DisplayIcon(@"no power")
```

```
    exit
```

```
end if
```

```
if valid_draw = 0 then
```

```
    DisplayIcon(@"no draw pan")
```

```
    exit
```

```
end if
```

```
if (Checked@"power" = 0) | (Checked@"pen" = 1) | (Checked@"measureX" = 0) |
```

```
(Checked@"measureY" = 0) then
```

```
    DisplayIcon(@"no power in draw")
```

```
    exit
```

```
end if
```

```
if ~auto_adjusted then
```

```
    DisplayIcon(@"no adjusted")
```

```
    exit
```

```
end if
```

```

if display_load <> 0 | display_position <> 0 then

    DisplayIcon(@"no zero")

    exit

end if


--everything ok, go up now

go_up_now := 1

points_current := 0


f_enlarge_start := f_enlarge_end := 1

Eval("DisplayIconnoerase(@"movie_ "^current_material^"3\\")")

Eval("EraseIcon(@"movie_ "^current_material^"2\\")")

current_movie := 3

--f_enlarge_end := Eval("MediaLength@"movie_ "^current_material^"3\\")


--play_rate := 2


if current_material = 1 then ----- Steel

    point1_list := ReadExtFile(FileLocation^"lib_\\line_s.txt")

    temp_data := 30847.9+Random(-0.05, 0.05, 0.01)

    temp_x := 450 ----I get the data from the file line_s.txt, where the movie should be started

    temp_load := temp_data / 122 --(the max value of the curve)

    temp_posi := (16.53+Random(0, 0.2, 0.01)) / GetLine(point1_list, LineCount(point1_list))

```

```

        exit

    end if

    exit

    --everything ok, go up now

    Level 3 --End?-steel

    if points_current > LineCount(point1_list) / 2 then

        path := 2    --no draw, return immediately

        go_up_now := 0

        exit

    end if

    if points_current = temp_x then

        f_enlarge_end := Eval("MediaLength@"^movie_ "^current_material^3\^")

    end if


    if points_current = 80 then

        DisplayIconNoErase(@"line of huayi")

    end if

    if points_current = 145 then

        EraseIcon(@"line of huayi")

    end if


    if points_current = 220 then

        DisplayIconNoErase(@"line of jinsuo")

```

end if

if points_current = 350 then

EraseIcon(@"line of jinsuo")

MediaPlay(@"wav.avi")

end if

To somewhere=4|=5|=10(go up now)

--f_enlarge_start := f_enlarge_end := f_enlarge_end + 1

points_current := points_current + 1 --total points, initialize value 0

pointx := startx + GetLine(point1_list, points_current * 2-1)

pointy := starty - GetLine(point1_list, points_current * 2)

Eval("DisplayIconNoErase(@"point"^points_current^"\")")

path := 1 --to move

if points_current < 300 then

f_enlarge_end := INT(points_current / 60)

else

f_enlarge_end := INT(points_current / 20)

end if

display_load := temp_load * GetLine(point1_list, points_current * 2)

display_position := temp_posi * GetLine(point1_list, points_current * 2 - 1)

Appendix 6 A CD-ROM of the courseware

Name: Virtual Laboratory in Materials Science

Publisher: CRTVU Press

System Requirements:

Windows: Windows98/Me or Windows NT4.0/2000/XP or above

RAM: 128 MB or above

Display: Standard VGA, 32-bit true color

Pentium-III 1G or faster processor

CD-ROM driver

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List of Abbreviations (acronym)

ABET: Accreditation Board for Engineers and Technologists
CAI: Computer Assisted Instruction
CAL: Computer Assisted Learning
CCRTVU: China Central Radio and TV University
CISAER: Course on the Internet: Survey, Analysis, Evaluation, Recommendation
CMC: Computer Mediated Communication
CML: Computer Managed Learning
CRIDALA: Conference on Research in Distance Education & adult Learning in Asia
CRTVUs: China Radio and TV University System
ICCE: International Council for Correspondence Education
ICDE: International Council for Distance Education
ICTs : Information and Communications Technologies
IMM: Interactive Multimedia
NJIT: the New Jersey Institute of Technology
NPL: National Physical Laboratory
PRTVUs: Provincial Radio and TV Universities
QAA: Quality Assurance Agency
SARTOR: Standards and Routes TO Registration
SPSS: Statistical Program for Social Sciences
UKOU: United Kingdom Open University
UNESCO: United Nations Educational, Scientific and Cultural Organization
VE: Virtual Environment
VR: Virtual Reality
VTLS: Virtual Test Laboratory System
WWW: World Wide Web